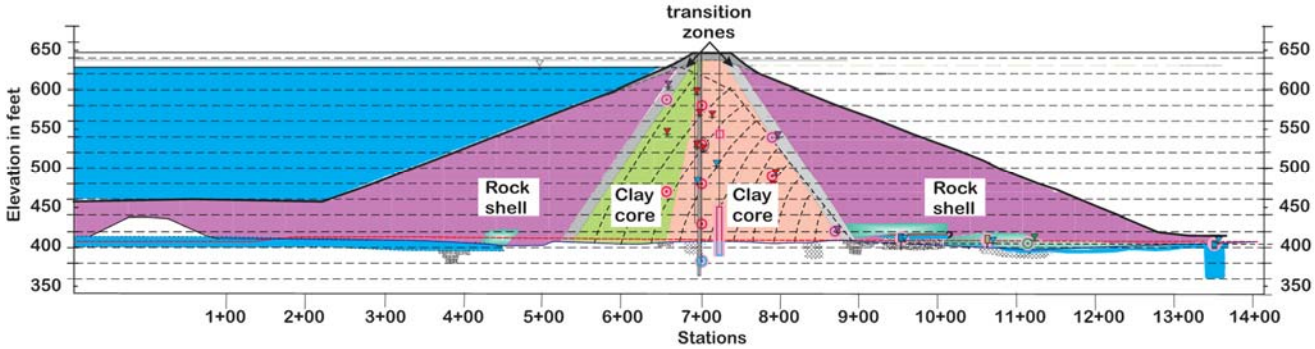
January 2019

2017-2018 SURVEILLANCE REPORT
LEROY ANDERSON DAM NO.72-9
Santa Clara County



Santa Clara Valley Water District

5750 Almaden Expressway, San Jose, CA 95118-3614 | (408) 265-2600 | www.valleywater.org

Santa Clara Valley Water District

January 31, 2019

Ms. Sharon K. Tapia, Chief
Division of Safety of Dams
Department of Water Resources
1416 Ninth Street
P.O. Box 942836
Sacramento, CA 94236-0001

Subject: Dam Safety Surveillance Report for Leroy Anderson Dam, No. 72-9, Santa Clara County

Dear Ms. Tapia:

Enclosed with this letter are two copies of our 2017-2018 Dam Safety Surveillance Report for Leroy Anderson Dam, No 72-9, Santa Clara County.

Our review of the surveillance data and our periodic safety inspections indicate that Anderson Dam and appurtenant structures appear to show normal response to their environment, aging process, and external events.

The District will continue with the current monitoring program and safety inspections and will keep DSOD informed of any significant changes pertaining to the surveillance or performance of Anderson Dam. During the current reporting period, there were no new activities at the site that would impact monitoring of this facility.

If you have any questions or comments, please contact me at 408-630-3796.

Sincerely,

Christopher Hakes, P.E.
Deputy Operating Officer
Dam Safety and Capital Delivery Division

Enclosures: 2017-2018 Dam Safety Surveillance and Monitoring Report for Leroy Anderson Dam

cc. H. Desai, S. Wu, H. Morshedian, L. Lopez

2017-2018 SURVEILLANCE REPORT
LEROY ANDERSON DAM NO.72-9
Santa Clara County

Date of photo 2013

Prepared for:
State of California
Department of Water Resources
Division of Safety of Dams
P.O. Box 942836
Sacramento, CA 95236

Prepared by:
Santa Clara Valley Water District
5750 Almaden Expressway
San Jose, CA 95118

January 2019

The analysis and interpretation of the instrumentation and other relevant data presented in this report has involved the application of certain graphical and statistical interpretive techniques common to the geosciences and earth dam engineering professions. The conclusions presented in this report were developed upon evaluating the performance of all instruments and other pertinent data during the specified period, and represent the professional judgment of its author. This report was published on January 31, 2019.

Prepared by:

Hossein Morshedian, P.E.
Associate Engineer
Dam Safety Program Unit

REGISTERED PROFESSIONAL ENGINEER
HOSSEIN MORSHEDIAN
C 87020
CIVIL
STATE OF CALIFORNIA

Quality Control/Quality Assurance

This report has been reviewed and approved for publication by the undersigned professional engineers. I attest and confirm that the report was prepared by the individual who signed the report under my immediate direction and supervision and that the conclusions and recommendations presented herein are reasonable and supported by District management.

Reviewed by:

Steven M. Wu, P.E. G.E.
Senior Engineer
Dam Safety Program Unit

Approved by:

Hemang Desai, P.E.
Engineering Unit Manager
Dam Safety Program Unit

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1.0 INTRODUCTION

1.1 *Scope and Purpose*

The focus of this 2017-2018 annual report is to review the data for overall accuracy and to make assessments of general data trends. If any significant geotechnical or operational events have occurred (i.e., earthquakes, sustained elevated reservoir levels, significant operational or maintenance changes, or dam instrumentation/monitoring changes), these are addressed to the appropriate level in this report. This report provides historical data plots covering the last 10 years (since ~ 2008) or since the installation date if less than ten years of instrument readings. The reader is referred to previous surveillance reports for earlier observations.

1.2 Anderson Dam Seismic Retrofit Project (ADSRP) Design Consultant

The design phase of the Anderson Dam Seismic Retrofit Project (ADSRP) continued through 2017-18, and will continue into 2019, under the consultant team known as the AECOM (formerly URS Corporation) ADSRP Design Team. Completion of retrofit construction is planned for 2026.

The seismic retrofit will, by necessity, include removal of all existing instrumentation. The ADSRP Design Team will re-evaluate the instrumentation and install new or replacement instruments as determined to be appropriate, in accordance with District requirements, and approval of DSOD and FERC.

1.3 2017 Focused Spillway PFMA

In August 2017, District ADSRP consultant, Black & Veatch (SCVWD, 2017) performed a Potential Failure Mode Analysis (PFMA) that focused on Anderson Dam spillway. Evaluation of potential failure modes of Anderson Dam spillway was requested by FERC due to a notable spillway failure of Oroville Dam in the winter of 2017. Spillway deficiencies identified in the PFMA will aid in developing possible short-term remediation if needed, and suitable long-term spillway design parameters for the District's ADSRP.

The findings of the 2017 focused PFMA were developed during a formal full-day 2017 Spillway PFMA session on August 17, 2017. This PFMA was attended by the following personnel, FERC Regional Engineer Edgar Salire, DSOD Engineers Chris Dorsey, and Ian Maki, District personnel H. Desai, K. Oven, B. Baker, and J. Nelson, and consultants for the ADSRP, including Black and Veatch, and AECOM.

1.4 Executive Summary

Our review of the surveillance data and our periodic safety inspections indicate that Anderson Dam and appurtenant structures appear to show normal response to their environment, aging process, and external events.

An external event in 2017 was the near record rainfall that caused Anderson Reservoir

to spill for 12 days from February 19, 2017 to March 1, 2017 and to exceed the 2011 reservoir restriction for 84 days from January 23, 2017 to April 16, 2017. These unusual conditions caused dam safety monitoring sensors to exceed established Threshold Values (TVs) and Action Levels (ALs). The District does not consider the 2017 high sensor readings as representative of adverse dam safety conditions because the TVs and ALs are tied to the 2011 reservoir restriction. Thus, the sensor readings are expected to be exceeded during reservoir conditions such as the unusual prolonged high reservoir levels in 2017.

Sometime during 2017, two In-Place Inclinometer sensors replaced in 2016 have subsequently failed again. The District believes the Little Dipper type of sensors no longer provide long-term reliable data and are not suitable for use at Anderson Dam. The District removed all the In-Place Inclinometer sensors on October 10, 2018. Future manual inclinometer probe data will be collected using the existing inclinometer casing.

The District will continue with the current monitoring program and safety inspections and will keep DSOD informed of any significant changes pertaining to the surveillance or performance of Anderson Dam.

During the current reporting period, aside from removal of the In-Place Inclinometers, there were no new activities at Anderson Dam that impacted surveillance and monitoring of this facility.

Due to seismic stability deficiencies of the Dam, Anderson Reservoir has been under a restriction of 45 feet at elev. 602.3 feet (NAVD88) since 2011. This restriction was approved by FERC and DSOD. In October 2017, the District decided to lower the water level further before the winter, to reduce the potential for Anderson Reservoir to spill or reach its seismic restriction level. Currently, Anderson is restricted to 58% of its full capacity (Elev. 592.3 feet) due to the seismic deficiencies and winter restriction. The current restriction will be in place until the seismic retrofit of the dam (ADSRP) is completed, which is currently anticipated to be the end of 2026.

Other than the high Anderson Reservoir levels and spilling during the extremely wet 2017 winter and the updated 2017 reservoir restriction, there are no substantive changes in Anderson Dam or changes in the response of Anderson Reservoir compared to previous years. The 2017 response is similar to the last Anderson Reservoir spilling event in 2006.

2.0 DSOD Comments

Our annual surveillance reports address comments by DSOD on surveillance reporting from the last DSOD field inspection report, or other dam related issues. DSOD performed two annual inspections of Anderson Dam on May 8, 2017 and April 3, 2018 and sent to the District inspection reports dated July 17, 2017 and May 24, 2018, respectively.

In that reports DSOD commented:

> *"Include piezometer cross-section plots that show piezometer water level (historic maximum and annual range), and the design (historic) phreatic surface. Also, a legend needs to be added to the survey monument time-plots so it is known which line depicts each monument."*

The above modifications have been accomplished in current report.

3.0 BACKGROUND INFORMATION AND METHODOLOGY

3.1 General

The Santa Clara Valley Water District (District) monitors data from the following instruments at Anderson Dam:

1) Thirty four (34) piezometers, consisting of:
    a. Three (3) downstream open well piezometers with,
        One (1) in the lower finer fill (LFF)
        Two (2) in foundation soils i.e. alluvium (Qa) and colluvium (Qc)
    b. Fifteen (15) vibrating wire piezometers in the downstream core
    c. One (1) vibrating wire piezometer in the upstream core
    d. Six (6) vibrating wire piezometers in the transition zone (two upstream and four downstream)
    e. Seven (7) vibrating wire piezometers in the foundation bedrock
    f. Two (2) vibrating wire piezometers in the foundation soils

Note1: The District permanently stopped collecting manual readings from pneumatic piezometers PPA-1 and PPA-2 in June 2014 due to failure of the outdated readout box.

2) Two (2) spillway underdrain weirs located downstream of the spillway
3) Fifteen (15) crest survey monuments, (Monument Nos. 16 through 30)
4) Three (3) spillway wing wall monuments (Monument Nos. 13, 14, & 15)
5) Seven (7) U.S. Geological Survey strong motion accelerometers on the crest and downstream of Anderson Dam
6) One (1) U.S.G.S accelerometer (NC.CADB) located off the dam at location 37.163460,-121.626450.
7) One (1) District seismograph located in the crest block house
8) One (1) headwater alarm located upstream of Anderson Dam
9) One (1) tailwater alarm is located along Coyote Creek approximately 1 mile downstream of Anderson Dam.

Note2: The District removed IPIs on Oct 10, 2018 and will collect routine manual inclinometer probe data using the existing inclinometer casing.

All new data covered in this report is presented in tabular form, and plotted to facilitate review. For the period of this report, data were collected annually for survey monuments and monthly for open well piezometers, and underdrain weirs. Data were collected from the vibrating wire piezometers via ADAS at nearly daily intervals as summarized in Section *4.7 Piezometers*. Crest monuments were surveyed at the times indicated (typically September or October of every year).

All elevation data presented in this report have been adjusted for the current datum used by the District Dam Safety Program, which is the North American Vertical Datum (NAVD) 1988. The newer datum is 2.80 feet higher than the old datum, National Geodetic Vertical Datum (NGVD) 1929, at this location.

In this report, open well and vibrating wire piezometer plots are grouped and presented as standard time series plots of piezometer and reservoir. Likewise, survey monuments are grouped and presented as time series plots.

Reported rainfall is measured at District Rain Gauge No. 41-2073, which is located a few hundred feet southeast of the left abutment of Leroy Anderson Dam.

3.2 Action Levels

The District previously developed and plotted Action Levels in the 2012 report (Nelson, 2012) based on historic data for each monitoring instrument. Based on input from DSOD and 2017 restricted reservoir level (592.3), we have reviewed and revised the definition and determination of 2012 Action Levels.

Action Levels of Piezometers – We calculated the Action Level values as the highest historic value plus 5 feet, so previously calculated single value Action Levels for the piezometers have been used as summarized on the bottom of Tables 2 and 3 in yellow highlight.

Updated Spillway Underdrain Weir Action Levels – We have elected to use a single value of ~114 gpm for the new Action Level for total underdrain discharge from weirs No. 1 and No. 2 at the left terminus of the spillway chute as summarized in Table 4 in yellow highlight. This is based on an estimated projection of the historic maximum at the reservoir elevation restriction ~592.3 feet.

Updated Survey Action Levels – The District did not update the +0.05 feet Action Level values for the annual monitored survey monument movement data from Anderson Dam crests as shown on Table 5. This Action Level is the current value for all District Dams.

Updated Inclinometer Action Levels – The District did not update the +0.05 feet Action Level values for the inclinometer movement data from Anderson Dam. This Action Level is the current value for all District Dams.

4.0 Monitoring Data and Analysis

Plate 1 shows the locations of crest monuments, spillway training wall monuments, vibrating wire and open well piezometers, accelerometers, and the spillway underdrain weirs at Anderson Dam. Transverse and longitudinal sections are shown in **Plates 2** through **6**. Specifically, **Plate 2** presents a transverse cross section A-A' through a minor section (Station 6+00) of the left abutment of the dam. **Plate 4** presents cross section B-B' near the maximum section of the dam. **Plate 6** presents a longitudinal section C-C' along the crest. The sections show vibrating wire piezometers and open well piezometers (two of which were installed during the Seismic Stability Evaluation, SSE1A). The pneumatic piezometers are no longer monitored.

Immediately following each of these cross sections is another cross section showing the annual range of each piezometer as horizontal lines and an arrow pointing to the maximum elevation of the phreatic surface in the complete piezometer data set. These are **Plates 3**, **5**, and **7**, titled "Piezometer Metrics".

Table 1 (page 10) presents a list of locations for each vibrating wire piezometer (VWP) and open well piezometers. **Table 2** (page 12) summarizes piezometric surface elevations (PSE in ft) of open well piezometers, **Table 3** (pages 14 and 15) summarizes monthly data from ADAS-recorded vibrating wire piezometers, and **Table 4** (page 20) summarizes spillway underdrain flow. **Table 5** (page 23), and **Table 6** (page 25) summarize survey data from the dam crest and spillway training walls.

All surveillance data are also shown graphically on **Figures 1** through **7**, and discussed later in the report. As indicated in Section 1.4.5 "Short Term" and "Long Term" Time Series Plots, the District will provide two types of time series plots in annual surveillance reports. The following are plots provided in this report:

● Long-term and short-term surveillance data of all piezometers at Anderson Dam are depicted as time-series plots as shown in **Figures 1-1** through **1-34**. For each piezometer, the long-term plot is at the bottom of each plot and the short-term piezometer surveillance for the same data are shown at the top. We decided to plot data since 2014 (~4 years) for the short-term plots of the vibrating wire piezometer data and long-term plots go back to 2004 (~14 years).

● **Figure 2** is a time-series plot of historic daily reservoir and rainfall data.

● The spillway underdrain weir surveillance data is depicted as a long-term time-series plot in **Figure 3.a** and as a short-term series plot in **Figure 3.b**.

● Long-term and short-term crest monument survey data from Anderson Dam are depicted in **Figures 4** and **5**, respectively. **Figure 4** shows all vertical displacement data for both upstream and downstream crest monument, while **Figure 5** shows all transverse displacement data for the same monuments.

● Long-term and short-term vertical spillway training wall monument survey data from Anderson Dam are depicted in **Figure 6**.

● Manually measured inclinometer data are depicted as “deflection versus depth” plots in **Figure 7**.

4.1 Dam Safety Program Unit Protocol and Outlier Data

The District Dam Safety Program Unit (DSPU) defined a rigorous formal process to respond to outlier data to determine if they represent unsafe or alarm conditions. That process is formally outlined in the District's QEMS process procedures (SCVWD, 2012), and consists of the following basic steps:

- *As soon as the outlier data is identified in our internal monthly data review and analysis, it is reviewed by District DSPU staff, and a preliminary inspection is performed, if needed, to determine if it is a simple reporting error or instrument malfunction.*
- *If not, District staff reports the incident to the District DSPU engineer and the District conducts a field inspection.*
- *If there is still a concern following the inspection, DSPU staff report the incident to DSPU Unit Manager and District management, and contact FERC and DSOD, if deemed necessary.*
- *Appropriate action is taken to resolve the concern.*
- *Outlier data and District response/assessment are reported in the next annual FERC and DSOD surveillance reports.*

Outlier data for each type of instrument monitored, if applicable, is discussed in the following sections. There were no instances of outlier data from piezometers and weirs during the current reporting period.

4.2 Data Gaps

Significant data gaps for ADAS instruments, and manual data collected from piezometers and underdrain flow weirs is defined as the absence of recorded instrument data for a period greater than about 1 month. A data gap for survey data is considered the absence of data over a period of plus or minus ~6 months outside the normally scheduled yearly survey.

As summarized below, no significant gaps occurred during the current reporting period. Since 2014, the District permanently discontinued reading pneumatic piezometers so the last data point was in June 2014.

Except for failure of the IPIs, all ADAS stations (VWPs) are currently working properly with no significant maintenance or performance issues.

4.3 Reservoir Restriction

Due to seismic stability deficiencies of the Dam, Anderson Reservoir has been under a restriction of 45 feet at elev. 602.3 feet (NAVD88) since 2011. This restriction was approved by FERC and DSOD. In October 2017, the District decided to lower the water level further before the winter, to reduce the potential for Anderson Reservoir to spill or reach its seismic restriction level. Currently, Anderson is restricted to 58% of its full capacity (Elev. 592.3 feet) due to the seismic deficiencies and winter restriction. The current restriction will be in place until the seismic retrofit of the dam (ADSRP) is completed, which is currently anticipated to be the end of 2026.

4.4 Annual Reservoir Fluctuation

Figure 2 shows the detail of reservoir fluctuation from 2007 through 2018 with gray shading that denotes recent data during the current surveillance period from January 2017 to the present. A highlighted event for 2017 is the spilling of Anderson Reservoir for the first time since 2006. During spilling, the reservoir reached a maximum of 632.1 feet on February 21, 2017, which is ~4.3 feet above the spillway lip elevation. It is also noteworthy that the 2017 event occurred ~ 1 year after one of the lowest reservoir levels since 2002 that occurred at the beginning of 2016 of ~562.0 feet. Over a ~1-year period 1/4/16 to 2/21/17) the reservoir level increased ~70 feet. During the previous ~5-year drought there has been an overall lowering of maximum reservoir excursions. The last time Anderson Reservoir spilled was in April 2006 (Nelson and Volpe, 2006).

The preponderance of rainfall for any given calendar year typically occurs during January through April/May.

4.5 2017 Spilling Event and Sensors that Exceeded Action Levels (ALs)

Excursions of seven vibrating wire piezometers and 2 spillway underdrain weirs exceeded their respective ALs (VWPs and Spillway Discharge Weirs). These noteworthy responses, depicted on Figures 1 through 3, are attributed exclusively to a rapidly rising and spilling reservoir during 84 days from January 23, 2017 to April 16, 2017, when levels were above the 2011 reservoir restriction. The reservoir spilled for a total of 12 days from February 19, 2017 to March 1, 2017. The established ALs for all piezometer sensors (Nelson, 2016a) are directly tied to the restriction elevation.

4.6 Tailwater and Headwater Alarms

No tailwater or headwater alarms occurred during the current reporting period.

In October 2011, the District implemented a Downstream Tailwater System and Upstream Headwater System to improve detection time for Time-Sensitive Emergency Action Plans (EAPs) downstream of Anderson Dam. An existing downstream gauge station 82, located ~1 mile downstream on Coyote Creek was upgraded to serve as a

tailwater alarm system. A suitable headwater monitoring system has been established upstream of the dam. The District has developed suitable action levels and procedures for directly responding to tailwater and headwater alarms.

The following general procedures are performed for notification of tailwater and headwater alarms. The District's ALERT system has a dual notification capability to the On-Call District Hydrographer staff for redundancy. The system pages and starts an autodialer that contacts the On-Call Hydrographer, who then notifies Dam Safety Program Unit staff with a page, phone call, and/or e-mail. The On-Call Hydrographer verifies that the alarm is real and contacts dam safety program staff with the results, and then resets the alarm.

4.7 Piezometers

Table 1 summarizes pertinent data of the vibrating wire piezometers (VWP), and open well piezometers, including location in the dam, tip elevation and surface elevation. These include locations of the piezometers include 15 VWPs in the downstream core (Zone 3) of the embankment, 1 VWP in the upstream core (Zone 2) (with core piezometers shown as red symbols in **Plates 1** through **4**), 4 VWPs in the downstream transition zone (purple symbols), 2 VWPs in the upstream transition zone (purple symbols), 2 VWPs and 2 open wells in alluvium/colluvium (green symbols), one open well in the Lower Finer Fill (olive green) and 7 VWPs in foundation Franciscan Complex bedrock (blue symbols).

For the period of this report, ADAS VWP data were collected four times daily (every 6 hours). Manual non-ADAS piezometers OW-1, OW-2, OW-3 are collected approximately once a month.

Plates 1 through **4** show Anderson Dam embankment piezometers in red, bedrock abutment and foundation piezometers in blue, transition zone piezometers in yellow, and one Lower Finer Fill piezometer in olive green (OW-2). Consequently, the symbol in the section views (**Plates 3** and **4**) show both red for the upper part and blue for the lower part.

The following sections provide information on grouped piezometers in the order of 1) open well piezometers, and 2) vibration wire piezometers.

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Table 1
Locations of Vibrating Wire Piezometers
and Open Well Piezometers
Leroy Anderson Dam

Embankment Piezos		
Downstream Core Zone 3	Tip Elev. (ft)	Surface Elev. (ft)
1) 72-9-02	480	647
2) 72-9-03	531	647
3) 72-9-04	580	647
4) 72-9-05	484	631
5) 72-9-10	430	647
6) 72-9-11	480	647
7) 72-9-12	530	647
8) 72-9-13	580	647
9) 72-9-20	550	647
10) 72-9-22	450	647
11) 72-9-23	500	647
12) 72-9-24	550	647
13) 72-9-26	550	647
14) 72-9-29	444	614
15) 72-9-30	490	614
Upstream Core Zone 2	Tip Elev. (ft)	Surface Elev. (ft)
16) 72-9-14	470.0	630.0

Transition Zone		
Downstream	Tip Elev. (ft)	Surface Elev. (ft)
17) 72-9-07	557	619
18) 72-9-08	518	602
19) 72-9-16	539	614
20) 72-9-17	421	583
Upstream	Tip Elev. (ft)	Surface Elev. (ft)
21) 72-9-06	587.0	631
22) 72-9-15	587.0	630.0

Foundation Fill - Lower Finer Fill		
Foundation	Tip Elev. (ft)	Surface Elev. (ft)
23) OW-2	406	508

Bedrock Foundation		
Foundation	Tip Elev. (ft)	Surface Elev. (ft)
24) 72-9-01	453	647
25) 72-9-9B	382	647
26) 72-9-18	580	647
27) 72-9-19	516	647
28) 72-9-21	400	647
29) 72-9-25	500	647
30) 72-9-27	585	647

Alluvial/Colluvial Foundation		
Foundation	Tip Elev. (ft)	Surface Elev. (ft)
31) 72-9-28	405	486.0
32) 2-9-31	600	647
33) OW-1	399	417
34) OW-3*	408	551

Pertinent data for the vibrating wire piezometers of Anderson Dam are summarized in Table 1. As summarized in Table 1, locations of the piezometers include 15 VWPs in the downstream core (Zone 3) of the embankment, 1 VWP in the upstream core (Zone 2) (with core piezometers shown as red symbols in Plates 2, 3, and 4), 4 VWPs in the downstream transition zone (yellow symbols), 2 VWPs in the upstream transition zone (yellow symbols), 2 VWPs in alluvium/colluvium (green symbols), and 7 VWPs in foundation Franciscan Complex bedrock (blue symbols).

4.7.1 Open Well Piezometers

As required by FERC, the District installed an open well standpipe piezometer (OW-1) in August 2003 about 50 feet downstream of the downstream toe of the dam, and about 100 feet north-northwest of the Coyote Creek Turnout Facility. This piezometer was installed to monitor the phreatic surface in native ground immediately downstream of the embankment toe.

Open well piezometers consist of a pipe with perforations targeting specific geologic horizons to measure the phreatic surface. The vibrating wire piezometers are electronic sensors that measure changes in ambient pressure utilizing a diaphragm attached to a taut wire. The frequencies in hertz (Hz) of the sensor, which changes as ambient pressure affect the diaphragm, are measured by ADAS, or in the field by a readout box, if necessary.

At Anderson Dam, the open wells typically consist of slotted polyvinyl chloride (PVC) pipe vented to the atmosphere. As required by FERC, OW-1 has stainless steel casing

(Nelson, 2003). The open wells at Anderson Dam, termed "standpipe piezometer", are slotted or porous over a limited section, typically the bottom 18 inches of the well. The slotted or porous portion is isolated by subsurface seals so that only the water pressure in the materials immediately adjacent to the piezometer tip is measured. Open wells OW-1, 2, and 3 at Anderson Dam are standpipe-type piezometers.

In 2009 AMEC/Geomatrix (2009d) installed two open well standpipe piezometers (OW-2 and OW-3) through the downstream shell into foundation materials in two of the borings (DH9-37SPTb and DH9-49, respectively) to provide phreatic surface information needed to assess the Seismic Stability Evaluation (SSE1A) of Anderson Dam.

As summarized in Table 1, piezometer OW-2 targets the phreatic surface of a lower fine-grained unit of rockfill embankment encountered during the SSE1A investigation and identified as the “Lower Finer Fill” (LFF) at depths between 89 feet and 105 feet (~elev. 403 feet and 419 feet). Well OW-3 targets the phreatic surface of various foundation soils including construction haul road fill and alluvium at depths between 132 feet and 141 feet (~elev. 410 feet and 418 feet). It is noteworthy that because OW-2 is located at a low elevation beneath the embankment this open well is functioning as a foundation piezometer and thus is grouped with other foundation piezometers.

The locations of the open well piezometers are shown in **Plates 1** and **3**.

4.7.2 Open Well Piezometer Data

Recent open well piezometer data collected since our last report (Baker, 2017) from January 2017 through December 2018 are summarized in **Table 2**. Also, shown at the bottom of **Table 2** are **ALs** (yellow shading) for each piezometer.

Figures 1-32 through 1-34 show open well piezometric levels as piezometric surface elevation (PSE), and reservoir levels data for the most recent 8+ year period from Late-2009 through December 2018. **Table 2** shows data since our 2016 surveillance report (Baker, 2017).

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Table 2
Recent Piezometric Data - Non-ADAS Read Piezometers
Leroy Anderson Dam

Date	Reservoir Level (ft)	OW-1	OW-2	OW-3	Monthly Rainfall (in)
		Piezometric Surface Elevation (ft)			
1/12/17	592.3	405.6	406.1	411.4	12.0
2/16/17	627.1	406.7	407.1	411.3	9.1
3/14/17	621.6	405.3	406.2	411.3	2.4
4/13/17	604.4	404.8	406.0	411.4	2.0
5/18/17	591.5	405.9	405.9	411.1	0.0
6/22/17	590.4	405.8	406.1	411.1	0.2
7/18/17	587.2	405.7	406.0	411.1	0.0
8/15/17	NR	NR	NR	NR	0.0
9/19/17	578.8	406.2	406.7	411.8	0.0
10/18/17	571.7	406.5	406.7	411.5	0.1
11/15/17	563.6	405.8	406.6	411.5	2.3
12/14/17	555.6	406.5	406.7	412.0	0.0
1/19/18	548.3	406.3	406.6	411.5	3.6
2/21/18	547.4	405.9	406.4	411.6	0.2
3/19/18	555.1	405.2	406.0	411.9	3.4
4/18/18	565.2	405.8	406.4	411.7	1.8
5/16/18	576.5	405.5	406.0	411.3	0.0
6/13/18	577.0	405.6	406.1	411.3	0.0
7/17/18	571.8	405.8	406.1	411.1	0.0
8/15/18	566.8	407.7	406.2	412.0	0.0
9/14/18	562.2	406.2	406.0	411.2	0.0
10/15/18	556.5	405.7	405.9	411.2	0.0
11/14/18	553.2	405.8	406.2	411.1	3.4
12/13/18	550.1	405.9	406.2	411.1	1.8
Action Levels *		411	412	417	

Notes:
1) Piezometer data is Piezometric Surface Elevation (PSE in feet)
2) PSE = pressure head (ft) + elevation head (ft)
3) basis of elevations is NAVD 1988 - values in this table are 2.8 feet higher than NGVD 1929
4) NR = no reading taken
5) Installation dates: OW-1 on 8/5/03, OW-2 on April 30, 2009, and OW-3 on May 1, 2009
6) * Yellow shading = Action Levels (ALs): see Nelson 2016b
7) file: W:\Geology\DAMS\Data\Pz\Anderson.xls\And Table1 Piez Data

As shown in **Figures 1-32 through 1-34**, since installation of the open wells OW-1, OW-2, and OW-3, the piezometric surface in these wells have varied over relatively narrow ranges. For the reporting period, piezometric elevations in OW-1 (located about 50 feet from the downstream toe of the dam) were consistently ~elev. 404.8 feet to 407.7 feet,

which corresponds to a depth of ~9 ½ feet to 12 feet below ground surface. OW-2 has varied from elev. ~405.9 feet to ~407.1 feet (~101 feet to 102 feet below ground surface) and OW-3 has varied from elev. ~411.1 feet to 412.0 feet (~139 feet below ground surface).

Overall, the data indicates that fluctuations in open well piezometric levels show minimal response to fluctuations in reservoir level.

The open well piezometer data appear to be providing reliable and consistent data during the entire surveillance period.

Based on recent data, during 2017-18, open well PSE values are well below the Action Levels (ALs).

4.7.3 Vibrating Wire Piezometers

Vibrating wire piezometers measure pore water pressures in the immediate vicinity of the electronic sensor. All vibrating wire piezometers are read by the Automated Data Acquisition System (ADAS). Manual readings can be taken with a readout box that is attached to 4 wire leads at the ground surface, where two wires measure frequency of vibration of the sensor in hertz. Hertz readings are converted to pore pressures using calibration constants for each sensor provided by the manufacturer Slope Indicator Company.

From September 2006 through January 2007, the District installed 31 vibrating wire piezometers (VWP) during the 2006/2007 Dam Instrumentation Project (DIP) (Fugro West, 2007). The District manually collected data from 31 VWPs from their installation in late December 2006 until implementation of ADAS in early December 2008. Most data (except open wells, or OWs) since December 2008 has been automatically collected by ADAS. The locations of the VWPs are shown in plan view in **Plates 1** and in section views in **Plates 2**, **3**, and **4**.

4.7.4 Vibrating Wire Piezometer (VWP) Data

Table 3 summarizes selected monthly piezometer data for each VWP. For convenience, we selected readings from the ~middle of the respective month for the tabular data of ADAS VWPs, which is the approximate time monthly manual readings are taken for the non-ADAS VWPs. Also, shown at the bottom of **Table 3** are **ALs** (yellow shading).

Table 3
Recent Piezometric Data – Vibrating Wire Piezometers
Leroy Anderson Dam

Date	Reservoir Level (ft)	ADAS Read Piezometers 1	2	3	4	5	6	7	8	Monthly Rainfall (in)
1/15/2017	595.1	453.9	506.2	553.8	580.7	499.6	595.1	557.2	518.0	12.0
2/15/2017	627.3	453.9	506.6	554.5	580.8	500.4	627.1	557.1	518.0	9.1
3/15/2017	621.1	453.9	506.5	556.2	588.2	500.9	620.7	557.2	518.1	2.4
4/15/2017	603.1	453.9	506.3	558.9	587.1	502.1	602.8	557.1	518.0	2.0
5/15/2017	590.8	453.7	506.3	560.0	585.1	501.6	590.4	556.9	517.9	0.0
6/11/2017	590.9	453.7	506.4	560.1	583.6	501.7	590.4	557.0	517.9	0.2
7/15/2017	587.6	453.8	506.4	559.8	582.5	501.1	586.9	557.1	518.0	0.0
8/15/2017	583.4	453.7	506.4	559.4	582.0	500.7	587.1	556.9	517.9	0.0
9/20/2017	578.6	453.8	506.4	558.8	581.3	500.0	587.2	557.0	517.9	0.0
10/15/2017	572.8	453.9	506.3	558.2	580.8	499.9	587.5	557.2	518.1	0.1
11/15/2017	563.7	454.0	506.3	557.4	580.3	499.8	587.8	557.2	518.2	1.9
12/14/2017	555.6	453.9	506.2	556.5	580.0	499.3	587.8	557.1	518.2	0.0
1/19/2018	548.3	454.0	506.1	555.2	579.9	499.2	588.8	557.2	518.3	3.6
2/21/2018	547.4	454.1	506.1	554.1	579.8	498.9	589.7	557.3	518.5	0.2
3/19/2018	555.1	454.1	506.0	553.2	579.7	498.7	589.7	557.3	518.5	3.4
4/18/2018	565.2	454.1	506.0	552.2	579.5	498.3	589.5	557.3	518.5	1.8
5/16/2018	576.5	454.0	506.0	551.5	579.4	498.4	589.7	557.2	518.4	0.0
6/13/2018	577.0	453.7	505.8	550.9	579.3	498.3	589.9	556.9	518.2	0.0
7/17/2018	571.8	453.9	505.7	550.3	579.1	498.2	590.4	557.1	518.4	0.0
8/15/2018	566.8	453.8	505.6	550.0	579.0	498.2	590.5	557.0	518.4	0.0
9/14/2018	562.2	453.9	505.5	549.8	578.9	498.1	590.7	557.1	518.5	0.0
10/15/2018	556.5	454.0	505.3	549.4	578.8	497.7	590.8	557.1	518.6	0.0
11/14/2018	553.2	454.4	505.2	549.0	578.8	497.7	591.6	557.5	519.0	3.4
12/13/2018	550.1	454.3	505.1	548.6	578.8	497.7	591.3	557.4	519.9	1.8
Action Levels*		459	533	576	592	510	618	562	524	

Yellow shading = exceeded upper Action Levels (ALs), which are tied to 2017 reservoir restriction

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Table 3 (cont.)
Recent Piezometric Data – Vibrating Wire Piezometers
Leroy Anderson Dam

Date	Reservoir Level (ft)	ADAS Read Piezometers								Monthly Rainfall (in)
		9B	10	11	12	13	14	15	16	
1/15/2017	595.1	482.6	522.4	526.6	565.0	586.6	542.9	596.5	540.5	12.0
2/15/2017	627.3	489.9	523.3	527.8	567.7	598.6	544.6	628.5	540.6	9.1
3/15/2017	621.1	485.3	523.8	528.3	571.4	608.1	546.5	622.7	540.3	2.4
4/15/2017	603.1	481.8	524.4	528.6	573.6	603.8	548.0	605.1	540.1	2.0
5/15/2017	590.8	481.1	524.8	529.0	573.1	597.1	548.3	592.0	539.9	0.0
6/11/2017	590.9	481.8	525.1	529.3	572.4	594.8	548.2	592.0	539.8	0.2
7/15/2017	587.6	481.2	525.2	529.6	571.5	593.0	547.9	588.6	539.8	0.0
8/15/2017	583.4	480.4	525.1	529.6	570.6	591.0	547.4	586.9	539.8	0.0
9/20/2017	578.6	479.8	524.9	529.5	569.3	588.9	546.7	586.9	539.7	0.0
10/15/2017	572.8	479.0	524.6	529.2	568.3	587.7	546.1	587.0	539.8	0.1
11/15/2017	563.7	477.7	524.0	528.7	566.7	586.5	545.0	587.1	539.8	1.9
12/14/2017	555.6	484.2	515.3	528.2	565.1	585.7	543.8	587.1	539.8	0.0
1/19/2018	548.3	483.2	514.4	527.3	562.9	585.1	542.0	587.6	539.7	3.6
2/21/2018	547.4	482.9	513.5	526.5	561.1	584.8	540.4	587.5	539.7	0.2
3/19/2018	555.1	483.6	512.8	526.0	560.1	584.7	539.3	587.6	539.6	3.4
4/18/2018	565.2	484.4	512.2	525.6	559.4	584.6	538.4	587.7	539.7	1.8
5/16/2018	576.5	485.1	511.8	525.3	559.4	584.6	538.0	587.4	539.8	0.0
6/13/2018	577.0	483.8	511.4	525.0	559.5	584.8	537.9	587.1	539.7	0.0
7/17/2018	571.8	483.1	511.1	524.6	559.7	584.6	538.1	587.1	539.7	0.0
8/15/2018	566.8	482.4	510.9	524.3	559.7	584.4	538.1	587.0	539.5	0.0
9/14/2018	562.2	481.9	510.7	524.0	559.3	584.2	537.9	587.0	539.5	0.0
10/15/2018	556.5	481.5	510.4	523.7	558.7	584.0	537.5	586.9	539.5	0.0
11/14/2018	553.2	481.3	510.0	523.4	558.0	583.8	536.9	587.2	539.8	3.4
12/13/2018	550.1	481.0	509.5	523.0	557.2	583.7	536.1	587.2	539.3	1.8
Action Levels*		514	543	560	590	613	565	619	546	

Yellow shading = exceeded upper Action Levels (ALs), which are tied to 2017 reservoir restriction

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Table 3 (cont.)
Recent Piezometric Data – Vibrating Wire Piezometers
Leroy Anderson Dam

Date	Reservoir Level (ft)	ADAS Read Piezometers								Monthly Rainfall (in)
		17	18	19	20	21	22	23	24	
1/15/2017	595.1	420.3	580.0	516.1	571.5	453.2	518.4	546.8	562.9	12.0
2/15/2017	627.3	420.3	579.9	516.1	581.0	455.5	519.1	549.1	563.8	9.1
3/15/2017	621.1	420.3	585.1	516.1	589.4	455.4	519.9	551.8	564.6	2.4
4/15/2017	603.1	420.2	581.3	516.1	587.0	453.8	520.8	553.6	565.4	2.0
5/15/2017	590.8	420.1	579.8	515.9	581.5	453.3	521.3	553.6	566.3	0.0
6/11/2017	590.9	420.1	579.8	516.0	579.3	453.2	521.5	553.4	567.1	0.2
7/15/2017	587.6	420.1	579.9	516.0	577.8	452.9	521.5	552.9	567.6	0.0
8/15/2017	583.4	420.0	579.8	515.9	576.0	452.7	521.3	552.3	567.7	0.0
9/20/2017	578.6	420.1	579.9	515.9	573.8	452.4	521.0	551.3	567.5	0.0
10/15/2017	572.8	420.2	580.0	516.1	572.0	452.2	520.7	550.4	567.2	0.1
11/15/2017	563.7	420.2	580.0	516.1	569.1	452.0	520.1	549.2	566.6	1.9
12/14/2017	555.6	420.2	580.0	516.1	566.2	451.7	519.5	547.9	565.9	0.0
1/19/2018	548.3	420.2	580.0	516.1	562.9	451.4	518.6	546.1	565.0	3.6
2/21/2018	547.4	420.3	580.1	516.2	560.6	451.3	517.6	544.5	564.3	0.2
3/19/2018	555.1	420.3	580.1	516.2	559.4	451.3	517.0	543.5	563.7	3.4
4/18/2018	565.2	420.3	580.1	516.2	559.1	451.9	516.3	542.7	563.1	1.8
5/16/2018	576.5	420.2	580.0	516.1	560.4	452.0	515.9	542.3	562.6	0.0
6/13/2018	577.0	420.0	579.7	515.9	563.2	451.7	515.6	542.1	562.3	0.0
7/17/2018	571.8	420.1	579.9	516.0	564.6	451.5	515.4	542.0	561.8	0.0
8/15/2018	566.8	420.1	579.8	516.0	564.3	451.3	515.3	541.8	561.4	0.0
9/14/2018	562.2	420.1	579.9	516.0	563.1	451.2	515.1	541.5	561.0	0.0
10/15/2018	556.5	420.2	580.0	516.1	561.6	450.9	514.8	541.0	560.6	0.0
11/14/2018	553.2	420.6	580.3	516.5	560.1	450.9	514.5	540.4	560.3	3.4
12/13/2018	550.1	420.5	580.2	516.4	558.8	450.8	514.1	539.7	560.0	1.8
Action Levels*		426	585	522	599	460	540	571	583	

Yellow shading = exceeded upper Action Levels (ALs), which are tied to 2017 reservoir restriction

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Table 3 (cont.)
Recent Piezometric Data – Vibrating Wire Piezometers
Leroy Anderson Dam

Date	Reservoir Level (ft)	ADAS Read Piezometers							Monthly Rainfall (in)
		25	26	27	28	29	30	31	
1/15/2017	595.1	554.0	573.9	589.4	411.9	476.2	493.8	601.6	12.0
2/15/2017	627.3	563.0	574.7	615.7	412.6	476.3	494.0	604.9	9.1
3/15/2017	621.1	566.8	575.8	611.4	412.0	476.3	493.9	603.5	2.4
4/15/2017	603.1	564.9	578.3	596.7	411.2	476.1	493.9	602.5	2.0
5/15/2017	590.8	561.1	580.6	587.0	411.1	476.0	494.0	602.4	0.0
6/11/2017	590.9	559.9	581.6	587.0	410.9	476.0	494.0	602.3	0.2
7/15/2017	587.6	558.6	581.7	584.9	410.7	476.1	493.8	602.1	0.0
8/15/2017	583.4	556.9	581.3	584.6	410.3	476.2	493.9	601.9	0.0
9/20/2017	578.6	554.9	580.6	584.7	410.2	476.1	494.0	601.6	0.0
10/15/2017	572.8	553.2	580.0	584.8	410.5	476.1	494.0	601.4	0.1
11/15/2017	563.7	550.2	579.1	584.8	410.4	476.0	494.0	601.4	1.9
12/14/2017	555.6	547.1	578.3	584.8	410.4	476.0	494.0	601.4	0.0
1/19/2018	548.3	543.4	576.8	584.8	410.3	475.8	494.0	601.3	3.6
2/21/2018	547.4	540.9	575.5	584.9	410.2	475.7	494.0	601.5	0.2
3/19/2018	555.1	540.0	574.5	584.9	410.2	475.6	494.0	601.5	3.4
4/18/2018	565.2	541.3	573.4	584.9	410.6	475.6	493.9	601.7	1.8
5/16/2018	576.5	544.1	572.4	584.8	410.5	475.6	493.9	601.8	0.0
6/13/2018	577.0	546.4	571.6	584.5	410.2	475.4	493.9	601.6	0.0
7/17/2018	571.8	546.8	571.0	584.7	410.2	475.3	493.7	601.5	0.0
8/15/2018	566.8	546.0	570.6	584.6	410.1	475.1	493.8	601.3	0.0
9/14/2018	562.2	544.7	570.2	584.6	410.1	474.9	493.7	601.2	0.0
10/15/2018	556.5	542.9	569.9	584.7	410.1	474.7	493.6	601.1	0.0
11/14/2018	553.2	541.2	569.7	585.1	410.3	474.5	493.5	601.2	3.4
12/13/2018	550.1	539.7	569.3	585.0	410.2	474.3	493.5	601.2	1.8
Action Levels*		576	601	611	417	482	514	609	

Notes:
1) Basis of elevations is NAVD 1988 - elevations are 2.80 feet higher than NGVD 1929
2) NR = piezometer readings not recorded by ADAS or manually
3) * Yellow shading = upper limit Action Levels (ALs) tied to 2017 reservoir restriction
4) file: W:\Geology\DAMS\Data\Pz\Anderson.xls\monthly

The old and recent data (obtained since our last report (Baker, 2017) from January 2017 through December 2018) is shown in **Figure 1**, which show time-series plots and cross plots of piezometric surface elevation (PSE) vs. time for each piezometer. The PSE is defined as the sum of the piezometer tip elevation (feet) and the hydraulic pressure head (feet). Reservoir elevation data is presented for reference.

During 2017-18, all VWP piezometer data appear to be providing reliable and consistent data during the entire surveillance period.

Based on recent data, during 2017-18, all VWP PSE values (except VWPs that responded to the 2017 Spilling) are well below the Action Levels (ALs).

4.7.5 Vibrating Wire Piezometer (VWP) Outlier Data

Since the 2016 ADAS retrofit project, previously noted outlier data from VWP-6 and VWP-31 are no longer experiencing erratic behavior (see Baker, 2017). We now consider the observed erratic behavior to have been due to faulty hardware/electronic problems with the sensor that were solved during the 2016 ADAS retrofit and not related to adverse embankment/foundations conditions with readings from both piezometers much greater than normal (100s of feet). The District will continue to monitor the behavior of VWP-31 and VWP-6 and will keep DSOD apprised if there are any changes to these, or any other sensors.

4.8 Spillway Underdrain System

There is no weir seepage monitoring of the embankment itself due to absence of historic observed seepage. An underdrain system, however, was installed in the spillway foundation to discharge probable reservoir water and groundwater that flows beneath the spillway. The concrete lined spillway is constructed on rock and dense terrace deposits on an elevated river terrace in the right abutment in an area that served as a borrow source for the rockfill shell. The underdrain system is constructed of 6, 8, and 12-inch diameter perforated pipe. Seepage collected by the center drainage system is measured by Weir No. 1. The remainder of the underdrain system collects seepage along the left side of the spillway from the downstream toe of the spillway crest to the spillway bucket. This seepage is measured by Weir No. 2.

Historically, two different methods for measuring Anderson Dam spillway underdrain discharge consisted of a former flow meter during the 1990s, which was changed to the current weir system in 2000. The initial discharge monitoring program spanned the period from 1993 to 1999 and consisted of manual measurements made using a flow meter that was attached to the “center” drainage system. This system of piping for the meter only collected seepage in the central portion of the spillway. The flow meter was removed during periods when the reservoir spilled to avoid damage or loss of the meter. During this period, the "left" drainage system could not be measured and was discharged through boulders that were providing slope protection downstream of the spillway bucket. Only with newer weir system could the “left” drainage be effectively measured.

The current weir system constructed in 1999 allowed all discharge to be measured for the first time, instead of only measuring a portion of the flow as occurred with the original center drainage system mentioned above. Weir No. 1 measures the seepage from the "center" drainage system (essentially replicating the data from the former flow meter), but is not affected by the restriction and backpressure created by the use of a meter, as was the old system that it replaced. Weir No. 2 measures the seepage collected along the left (southern) side of the spillway.

4.8.1 Spillway Underdrain Flow Data

Our surveillance reports only provide historic data plots covering the last 10+ years (since mid-2007). This report only shows plots of the weir discharge data and not historic spillway underdrain flow data collected using a flow meter. The older flow meter data are summarized in previous surveillance reports.

Figure 3 shows monthly rainfall and data from weirs No. 1 and No. 2 from 2012 through December 2018, with gray shading showing data since the 2016 report (Baker, 2017). **Table 4** shows recent data since the 2016 report (Baker, 2017). Also, shown at the bottom of **Table 4** are **ALs** (yellow shading) for the respective weir.

Table 4
Recent Weir Discharge Data – Spillway Underdrains
Leroy Anderson Dam

Date	Reservoir	Underdrain	flow (gpm)	Total flow
	Level (ft)	Weir No. 1	Weir No. 2	(gpm)
1/12/2017	592.3	8.1	4.9	13.0
2/16/2017	627.1	188.0	118.0	306.0
3/14/2017	621.6	168.0	2.3	170.3
4/13/2017	604.4	54.3	18.9	73.2
5/18/2017	591.5	23.3	4.9	28.2
6/22/2017	590.4	23.3	3.1	26.4
7/18/2017	587.2	14.8	4.9	19.7
8/15/2017	NR	NR	NR	NR
9/19/2017	578.8	4.9	2.3	7.2
10/18/2017	571.7	3.6	2.3	5.8
11/15/2017	563.6	3.1	2.3	5.4
12/14/2017	555.6	2.3	0.9	3.1
1/19/2018	548.3	1.8	0.4	2.2
2/21/2018	547.4	0.9	0.4	1.3
3/19/2018	555.1	0.9	2.3	3.1
4/18/2018	565.2	3.6	0.4	4.0
5/16/2018	576.5	2.3	2.3	4.5
6/13/2018	577.0	3.1	0.4	3.6
7/17/2018	571.8	0.9	2.3	3.1
8/15/2018	566.8	0.9	2.3	3.1
9/14/2018	562.2	3.1	0.9	4.0
10/15/2018	556.5	0.9	0.4	1.3
11/14/2018	553.2	0.9	0.4	1.3
12/13/2018	550.1	0.9	0.4	1.3
1/16/2019	548.4	3.6	0.9	4.5
Action Levels (Based on 2011 restriction)		184.0	116.0	259.0
Action Levels (Based on 2017 restriction)		81.0	45.0	114.0

Notes: 1) Weir No. 1 collects flow from the central portion of spillway
2) Weir No. 2 collects flow from the left side of the spillway
3) NR = No reading in August 2017
4) Yellow = Action Levels (before and after Oct 2017)
5) file W:\Geology\DAMS\Data\Pz\Anderson.xls\And Table 2 Weir data

During 2017, the combined flow from the weirs ranged from a low of ~5.4 gallons per minute (gpm) (in November 2017) to a high of ~306 gpm (in February 2017). The 2017 maximum is much less than the historic total weir discharge of 475 gpm, that occurred on April 17, 2006. The overall flow is relatively large due to spilling reservoir conditions as discussed in *Section 4.4 Annual Reservoir Fluctuation*.

During 2018, the combined flow from the weirs ranged from a low of ~1.3 gallons per minute (gpm) (in February, October, November, and December 2018) to a high of ~4.5 gpm (in May 2018). The 2018 maximum is much less than the Action Levels.

4.9 Survey Monuments

Fifteen original dam crest monuments were installed immediately after dam construction in 1951. The original monuments were spaced at intervals of 100-feet on center from the left abutment to the right abutment. The original monuments were replaced with 16 crest monuments after dam modifications in 1988.

Modifications to Anderson Dam in 1988 included raising the dam crest 4 to 7 feet and widening the spillway to accommodate new Probable Maximum Flood (PMF) discharge requirements. Consequently, the existing surface monuments consist of a newer monitoring instruments installed after the 1988 modifications. These consist of crest monuments Nos. 16 through 30 (Mon. No. 31 destroyed) and training wall monuments Nos. 13 through No. 15 as shown on **Plate 1** (plan section view) and **Plate 6** (transverse section view).

The training wall Monuments No. 13, No. 14, and No. 15, were a new feature, which allowed the two walls adjacent to the spillway weir to be monitored for movements. Roughly half the crest monuments are located along the downstream edge of the crest (Nos. 17, 19, 21, 24, 26, and 28) and half along the upstream edge of the crest (Nos. 18, 20, 22, 23, 25, 27, and 29). Monuments No. 16 and No. 30 are located at the left and right abutments, respectively. Mon. No. 31 was destroyed ~2004 during boat ramp work by the County of Santa Clara. Mon. No. 30 replaces No. 31 as a survey control monument.

As mentioned above, the crest monuments generally alternate between the downstream edge and upstream edge of the crest. Data plots have been grouped as either “upstream (U/S) edge” or “downstream (D/S) edge”. The location of the surface monuments are shown in **Plate 1** (plan view) and **Plate 6** (longitudinal section view).

For this report, the District presents monument survey data as plots of vertical displacement and lateral displacements. For the crest monuments, the District converted the monument coordinates determined by surveys, to perpendicular offsets from a line between points on both ends of the dam.

4.9.1 Dam Crest and Abutment Monuments

During the period of this report, crest monuments (No. 16 through No. 30) and training wall monuments (No. 14 and No. 15) were monitored at the locations shown in **Plate 1** (plan view) and in **Plate 4** (longitudinal section view). Monument No. 13 was monitored in 2015, which is the first time since 2001. After monument 31 was destroyed in ~2004, monument 30 was established as the left abutment control endpoint as the reference point to determine local transverse displacements.

During the period of this report, dam crest monuments No.16 through No. 30 were monitored and their locations are shown on **Plate 1**. The vertical and transverse data for Anderson Dam is presented in **Figures 4** and **5**, and summarized on **Table 5**. Net vertical and transverse displacements since the last surveillance report (i.e. from September 2016 to the September 2018 survey) is shown at the bottom of each data set on **Table 5**.

"Vertical" and "transverse" survey data collected since the last report (Baker, 2017) are shown as gray shading on **Figures 4** and **5**. The crest monuments generally alternate between the downstream edge and upstream edge of the crest. Data plots have been grouped as either "upstream (U/S) edge" or "downstream (D/S) edge".

Survey results of crest and abutment monuments indicate minimal horizontal and vertical displacements (less than 0.01 ft in the vertical plane and 0.01 in the horizontal plane) have occurred during this reporting period. These small displacements indicate that only minimal, normal displacements of the dam have occurred during this reporting period with no obvious trends.

Table 5

Vertical and Local Transverse Data - Crest and Abutment Monuments
Leroy Anderson Dam

Date	Monument **Vertical** Displacement (feet) (since 1988)														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
9/9/2016	0.00	-0.03	-0.05	-0.26	-0.20	-0.35	-0.31	-0.24	-0.37	-0.18	-0.13	-0.05	0.01	0.03	0.03
9/5/2017	0.01	-0.03	-0.06	-0.26	-0.20	-0.36	-0.31	-0.24	-0.37	-0.19	-0.13	-0.05	0.01	0.03	0.03
9/17/2018	0.01	-0.03	-0.06	-0.27	-0.21	-0.37	-0.32	-0.24	-0.38	-0.19	-0.13	-0.04	0.01	0.04	0.04
Action Levels *	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1
change in disp.	0.01	0.00	0.00	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.01	0.01	0.01
09/16 to 09/18	Average change since last survey =						0.00	or 0.04"							

Date	Dam Crest Monument Local **Transverse** Displacement (feet) (since 1988)														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
9/9/2016	0.00	-0.07	0.00	-0.14	-0.05	-0.18	-0.04	-0.11	-0.17	0.02	-0.02	0.10	0.01	-0.06	0.00
9/5/2017	0.00	-0.06	0.00	-0.15	-0.06	-0.18	-0.03	-0.11	-0.18	0.03	-0.04	0.09	0.00	-0.03	0.00
9/17/2018	0.00	-0.06	0.00	-0.14	-0.05	-0.19	-0.03	-0.12	-0.19	0.02	-0.04	0.09	-0.01	-0.04	0.00
Action Levels *	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1
change in disp.	0.00	0.00	0.00	0.00	-0.01	-0.01	0.01	-0.01	-0.02	0.00	-0.02	-0.01	-0.02	0.01	0.00
09/16 to 09/18	Average change since last survey =						0.00	or 0.06"							

Notes:

1) Negative transverse displacement signifies D/S movement
2) Positive transverse displacement signifies U/S movement
3) Displacement is net displacement since 1988
4) NR = monument not surveyed (Mon. 31 destroyed during new boat ramp construction; Mon. 30 new control pt)
5) file:W:\Geology\DAMS\Data\Survey\ANDsurvey.xls
6) Local Transverse data shown back calculated to 1988 - see text
7) Mons #16 and 30 are control points and do not show local transverse displacement
8) *Yellow shade = Action Levels (ALs): see Nelson 2012

As shown in **Figures 4** and **5**, the time-series lines are color coded to depict the relative thickness of the embankment (depth from crest to foundation) directly beneath each

monument on the vertical and transverse plots, where thicker dam sections are shown by hot colors and thinner sections are shown by cool colors. Red lines depict embankment thicknesses between ~150 feet and ~255 feet, blue is for embankment thicknesses between ~100 feet and 150 feet, and green is for embankment thicknesses between 0 feet and 100 feet. This gives a quick visual on whether monument movements are occurring on the more critical thicker sections relative to the less critical thinner sections of the dam.

The lines tend to group relative to color on **Figures 4** and **5**, with green lines (thinner section) generally plotting along the top, blue in the middle and red lines (thicker section) at the bottom of each plot. These trends indicate greater movements with time for thicker sections relative to thinner sections of the dam, which is typical for a large embankment dam with a significant differential in thicknesses. This appears to be generally true for both vertical and transverse displacements.

The crest monument surveys appear to be providing reliable and consistent data during the entire surveillance period.

Based on the recent data, during 2017-18, crest monument displacement values are well below the Action Levels (ALs).

4.9.2 Spillway Training Wall Monuments

Three survey monuments are located at the top of the spillway training walls, two on a wall on the left side of the spillway ogee (Mons. Nos. 14 and 15), and one on a wall on the right side of the ogee (Mon. No. 13), as shown in **Plate 1**. The District began to again provide survey data from Monument No. 13 in October 2015 (located on the right spillway wall), as shown on **Table 6,** with a time-series plot shown in **Figure 6**.

Previous spillway training wall horizontal and vertical survey results may be less reliable due to access issues. Because of the difficulty of accessing the monuments positioned at the bottom of a chain link fence, some errors may be introduced in the survey data from the spillway training walls (see Nelson and Volpe, 2004 for more information). Even with these limitations, this surveillance report provides historic data plots showing vertical displacement of Monuments 13, 14, and 15 in **Figure 6**.

The vertical data for the training walls presented in **Figure 6**, and summarized on **Table 6**. Net vertical displacements since the last surveillance report (from September 2016 to September 2018) is shown at the bottom of each data set on **Table 6**.

Also, shown at the bottom of **Table 6** are **ALs** (yellow shading) for each monument.

Survey results of training wall monuments indicate minimal horizontal and vertical displacements (less than 0.01 ft in the vertical plane) have occurred during this reporting period. These small displacements indicate that only minimal, normal displacements of the training walls have occurred during this reporting period with no obvious trends.

Table 6
Vertical Displacement Data
Spillway Training Wall Monuments
Leroy Anderson Dam

Date	Monument Vertical Displacement (feet)		
	13	14	15
9/9/2016	0.07	0.04	0.06
9/5/2017	0.06	0.03	0.06
9/17/2018	0.06	0.04	0.06
Action Levels*	±0.1	±0.1	±0.1
change in disp. 09/16 to 09/18	0.00	0.00	0.01

Avg. change since 9/16 = 0.00 or 0.01"

Notes:

1) Negative vertical displacement represents settlement

2) Positive vertical displacement represents heave

3) * Yellow shade = Action Levels (ALs): see Nelson 2012

4) file:W:\Geology\DAMS\data\survey\AndTranWallVert.xls

The spillway training wall surveys appear to be providing reliable and consistent data during the entire surveillance period.

Based on the recent data, during 2017-18, spillway training wall monument displacement values are well below the Action Levels (ALs).

4.10 In-Place Inclinometer Sensors (IPIs)

During the 2006-2007 DIP, the District installed an inclinometer casing in a crest borehole (IPI) near the maximum section of the dam that fully penetrated the embankment with the bottom of the casing embedded approximately 10 feet into competent stable bedrock (Fugro West, 2007). Six automated bi-axial sensors (in place inclinometers or IPIs) manufactured by Applied Geomechanics (model 906 Little Dipper IPIs, now manufactured by Jewel Instruments) were placed vertically in the single crest inclinometer boring using fiberglass rods that connect and suspend the individual IPIs successively in a vertical column.

The purpose of these instruments was to monitor gross deformations of the embankment as a result of events such as significant earthquakes or rapid draw-down of Anderson reservoir. To supplement the bi-axial sensor data, we also plan to perform conventional manual inclinometer surveys soon after significant seismic events, or more frequently as needed.

Due to erratic behavior in 2015 and 2016, the District replaced the top four in August 2016 during the 2016 ADAS Retrofit Project. During 2017 the District determined that the IPIs are unreliable and are not providing useful data.

The District believed these IPIs have not been robust and were no longer providing reliable data. Therefore, the foregoing IPIs were removed on October 10, 2018 and slope stability data will be collected by using a manual inclinometer probe by the District's Land Surveying unit.

The surveyors did collect manual inclinometer data from the Anderson crest on October 19, 2018 using a probe. These series of readings have been shown on **Figure 7** along with August 10, 2016 readings as a base. Graphs show consistency with action level (±0.1 ft) and no outlier data has been measured.

4.11 Strong Motion Accelerometers

4.11.1 U. S. Geological Survey Accelerometers

Seven Kinemetrics Model SMA-1 strong motion recorders (accelerometers) were installed in 1985 by the U.S. Geological Survey (U.S.G.S). Five accelerometers are installed on the downstream slope, one is situated about 150 feet south-southwest of the crest in the left abutment (see **Plate 1**), and one free field accelerometer is situated about 300 feet downstream of the toe of Anderson Dam. The accelerometers are operated and maintained by the U.S.G.S.

The current equipment installed in 2002 consists of a Kinemetrics accelerometer. The system can record 3 components (X, Y, Z) at 100 sps.

District Dam Safety Program Unit personnel request seismic data from the U.S.G.S. if any of the seven instruments have recorded seismic accelerations after significant earthquakes occur in the vicinity of Anderson Dam.

Other than small magnitude earthquakes (<4.6 mag), which produced minimal shaking during the current reporting period, there are no U.S.G.S. accelerometer data to report.

4.11.2 District Accelerometer

An Altus Etna strong motion accelerometer manufactured by Kinemetrics is securely mounted on the floor of the blockhouse on the crest of the dam as shown on **Plates 1** and **4**. The purpose of the accelerometer is to record accelerations in the vicinity of the dam in the event of an earthquake. The accelerometer continuously monitors ground acceleration and compares current acceleration levels to preset thresholds. When an excursion of the threshold acceleration value is detected, ADAS notifies the District with an alarm that the threshold condition (typically 0.03 g) was exceeded. No alarms were triggered during the period of this report.

The District's accelerometer in the ADAS Instrumentation blockhouse at the crest of the dam continuously monitors ground acceleration and compares current acceleration levels to preset thresholds. When an excursion past the threshold value for acceleration is detected, ADAS notifies the District with an alarm that the threshold value condition (typically 0.03 g) was exceeded. ADAS is set up to query the accelerometer for possible data at a 10-minute frequency during every 24-hour period. In addition, ADAS routinely retrieves data from VWPs and IPIs every 6 hours. Analysis of the accelerometer data will likely be referred to trained seismologists at the U.S.G.S. or the California Geological Survey (C.G.S.).

During the current reporting period (2017-18), there were no significant seismic events in the vicinity of Anderson Dam. Consequently, the strong motion accelerometer was not triggered and no acceleration data were collected. (see Section 9.1 Other Seismicity).

5.0 SEISMICITY

In 2014 SCVWD adopted DSOD's ShakeCast metrics for report inclusion criteria. The criterion used for including earthquakes in the annual DSOD Dam Safety reports was explained in the 2014 report and is roughly equivalent to a MMI of IV-V and a M4.5.

The greatest seismic load on Anderson Dam during the period of this report was a M4.6 that occurred on November 13, 2017 north-west of Pinnacles. The epicenter distance was 68.58 Km north of the dam. Table 7 shows that Anderson Dam had a seismic induced shaking modeled at 0.14% PGA and 0.1 cm/s PGV during the event.

Table 7
Pinnacles November 13, 2017 M4.6 seismic event that triggered the greatest shaking during the period of this report

Earthquake Scenario

M4.6 14.2 km (8.8 mi) NW of Pinnacles, CA, 2017-11-13 19:31:29

1	0	0	0	0

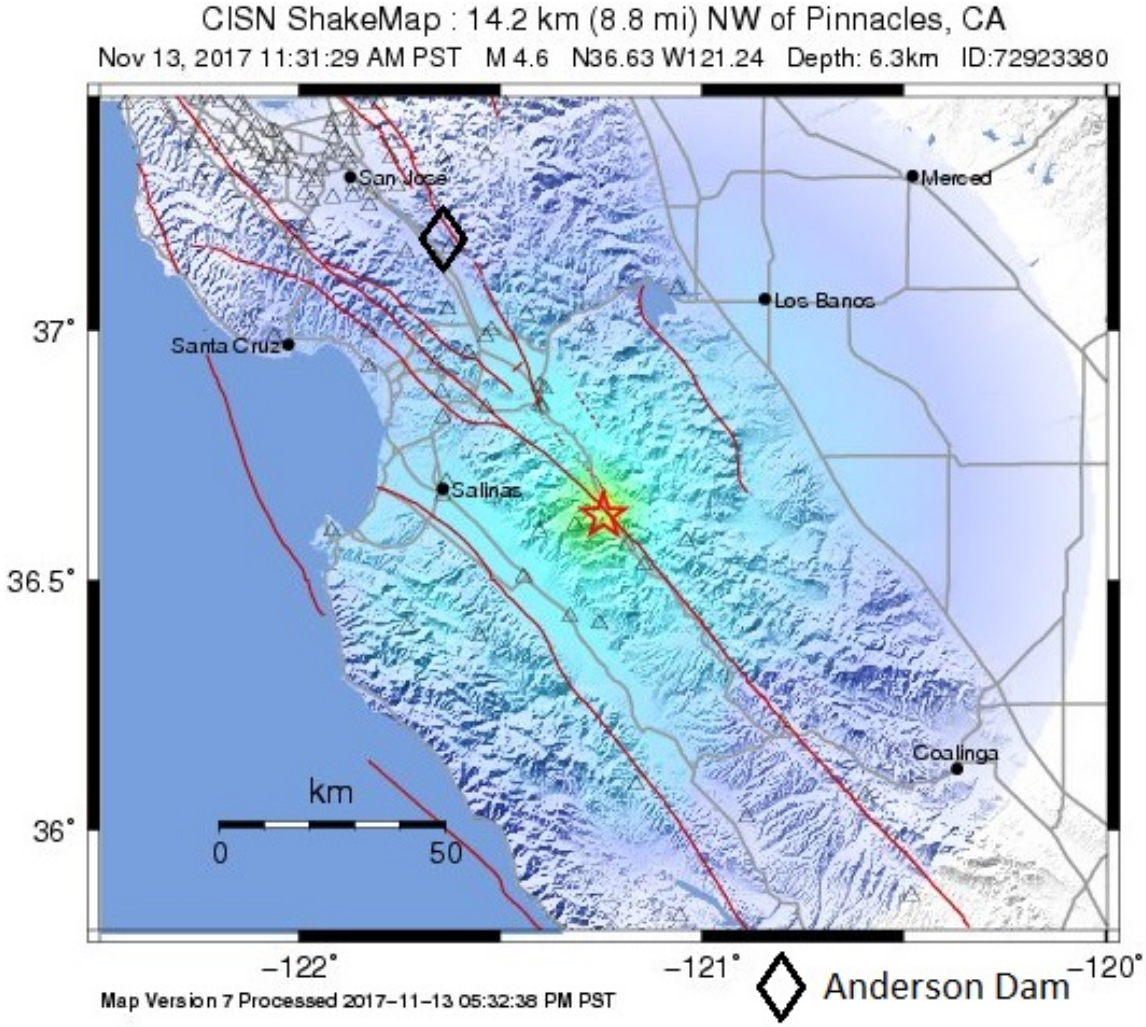
Show 10 entries Search:

Facility Type	Facility Name	Epi. Dist.	Priority	PGA	PGV	PSA 1.0s
ERRK	Anderson	68.58	GREY	0.14	0.1	0.13

The November 13, 2017 M4.6 earthquake is shown in **Figure 8**. It is a map of the modeled shaking from the earthquake by the USGS. Most of the facilities of the Santa Clara Valley Water District were in the MMI II or III zone. The red star symbol is the earthquake epicenter location.

In the 2014 annual report, we began using ShakeCast software to determine which earthquakes are included in the report. ShakeCast acquires ShakeMaps from the USGS immediately after a qualifying earthquake. ShakeMap uses modeled PGA values to estimate shaking intensities lower than V, it linearly combines PGA and PGV for intensities greater than V and less than VII, and it uses PGV for intensities greater than VII (see Wald et al., 1999b, for more details). See the table at the bottom of **Figure 8** for a correlation of the different metrics used to determine Instrumental Intensity. This event fell into the weak category of intensity experienced at Lenihan Dam.

Figure 8
USGS ShakeMap of November 13, 2017 M4.6 earthquake



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.1	0.5	2.4	6.7	13	24	44	83	>156
PEAK VEL.(cm/s)	<0.07	0.4	1.9	5.8	11	22	43	83	>160
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Wald, et al.; 1999

Table 8 shows the four levels of actions for increasing amounts of shaking intensity. Any earthquake that reaches the Green or higher Damage Level will be included in the annual report. For this report, there were no earthquakes reaching the Green level which corresponds with an instrumental intensity range from 4.5(IV) to just below 5.0(V).

Table 8

ShakeCast damage levels

ShakeCast Damage Level Administration

From this control panel you can add, edit, and remove damage levels.

Damage Level	Name	Description	Severity Rank	Max Severity	Action	
GREEN	No action required	No action required	100		Edit	Delete
YELLOW	Report and inspect next workday	Generate and review instrumentation report by the end of the next workday.	200		Edit	Delete
ORANGE	Generate report and inspect ASAP	Generate instrument report and inspect facility for damage within 24 hrs.	300		Edit	Delete
RED	Inspect & data report ASAP	This facility has probably suffered damage. Generate instrument report and inspect the dam. Possible drawdown requirement.	400	Yes	Edit	Delete

Add new damage level

Shown in Table 9 are the ranges of the metric used (Instrumental Intensity) for Anderson Dam that associate shaking intensities with damage level estimates shown above. The thresholds we use are the same as those used by DSOD for our facilities.

Table 9

Typical ShakeCast damage levels used at all dams

ShakeCast Facility Administration

From this control panel you can add, edit, and remove facilities. Predefined facility fragility setting values include 15% amplitude adjustment from mean to peak values.

Lookup Facility

Edit Facility Information

External Facility ID Requried (up to 32 characters)	Anderson (ERRK) *
Facility Name Requried (up to 128 characters)	Anderson Dam *
Facility Short Name (Up to 10 characters)	Anderson
Facility Type	Dam - Earth Rock *
Facility Description (Up to 255 characters)	Dam
Latitude (in decimal degree) Show Map Picker	37.165408 * <-> 37.165408
Longitude (in decimal degree)	-121.629525 * <-> -121.629525

Damage Level	Low Limit	High Limit	Metric
No action required	4.5 *	4.99999 *	Instrumental Intensity *
Report and inspect next workday	5 *	5.99999 *	Instrumental Intensity *
Generate report and inspect ASAP	6 *	6.99999 *	Instrumental Intensity *
Inspect & data report ASAP	7 *	12 *	Instrumental Intensity *

Submit Delete

The important takeaway on seismicity during the period of this report is that the trend of little seismic activity in recent years has continued.

6.0 CONCLUSIONS

For the period of January 2017 to December 2018, no significant modifications of the dam or appurtenant structures occurred that would impact the surveillance data or its interpretation.

No Vibrating Wire Piezometer exceeded their respective **Action Values**, during periods ranging

Spillway Underdrain Weir discharges of each weir (No. 1 and No. 2) and Total Weir Discharges (No. 1 + No.2) did not exceeded the respective **Action Levels**.

The surveillance data from Anderson Dam and the District's field observations confirm acceptable performance of the dam for the period of this report, with the dam showing normal responses to the environment, aging process, and external events. There were no surveillance instrumentation alarm conditions.

There are no substantive changes in Anderson Dam or changes in the response of Anderson Reservoir compared to previous years.

The District will continue with the current operating procedures and scheduled surveillance plans. Open well piezometers will be read monthly, crest and spillway training wall monuments will be surveyed annually, and spillway underdrain flows will be measured at the two weirs at least monthly. ADAS instrumentation (vibrating wire piezometers) will be read ~daily. In addition, site inspections and monument surveys will be conducted after a significant earthquake or other potentially disruptive activity.

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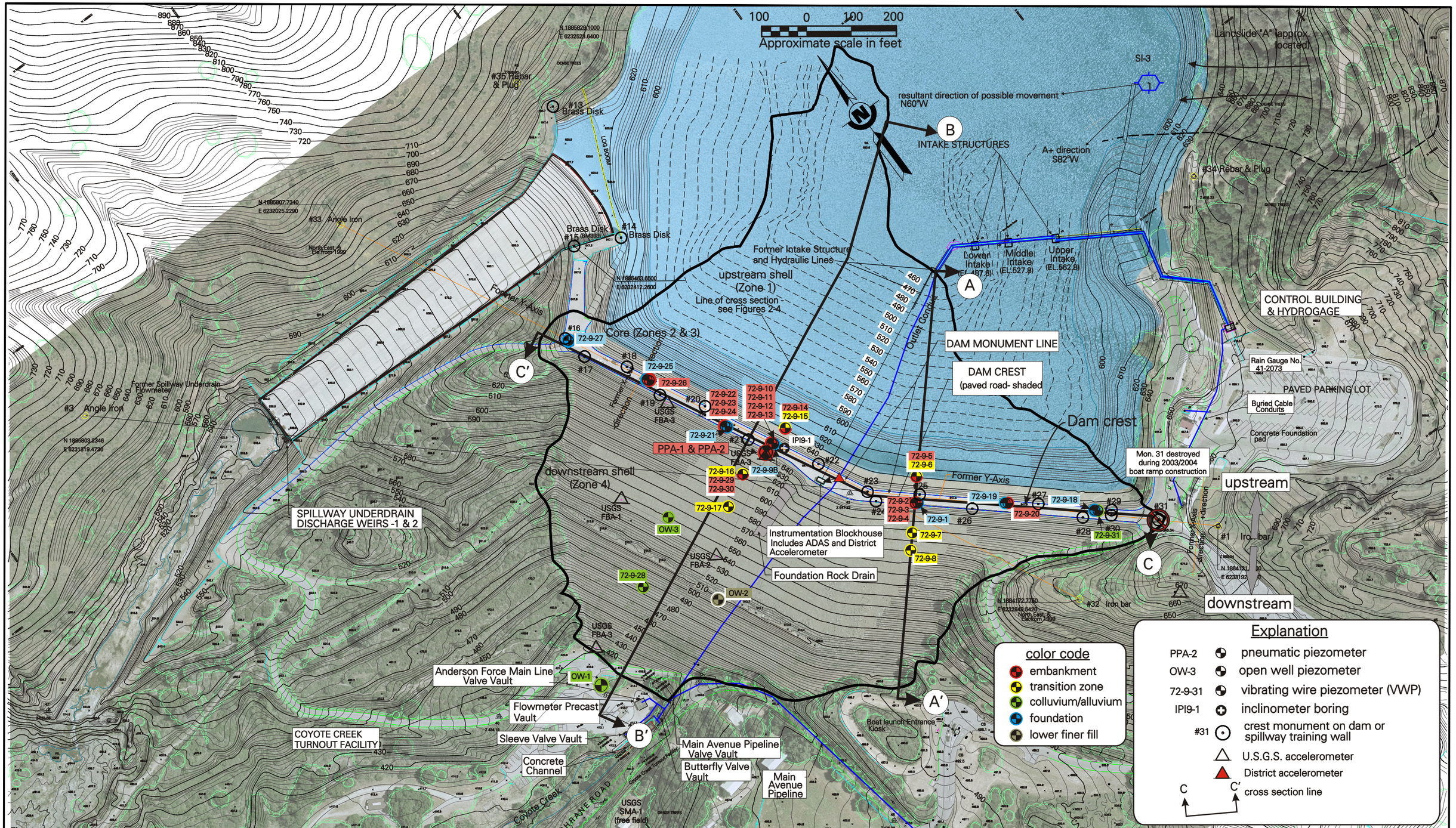


Reference information and notes:
1) This map is a compilation of aerial mapping, survey field data, and digitized construction maps. Maximum error could be ± one foot vertical and horizontal; error greater for upstream topographic lines (see note 7)
2) Grid is based on California Coordinate System, Zone III, NAD 83.
3) Elevations based on N.G.S. Vertical datum, NAVD 88. The DE between NGVD 29 and NAVD 88 is 2.80'
4) Photogrammetric mapping: Transvision, Photo date 12/11/97; color photo date 2006
5) file W:\geology\DAMS\Historic Dam Geology\anderson\ANDHistgeo.cdr
6) selected 1987-88 dam raise values in feet shown in red
7) upstream dam topography (dashed lines) from as-built 1988 "Leroy Anderson Dam Intake Structure Modification, Sheet 2, scale 1"=100', dated 1-8-88, from 10-7-87 aerial photography, modified to NGVD 88

DATE	12/08/11
DESIGN	JLN
DRAWN	JLN
CHECKED	SW

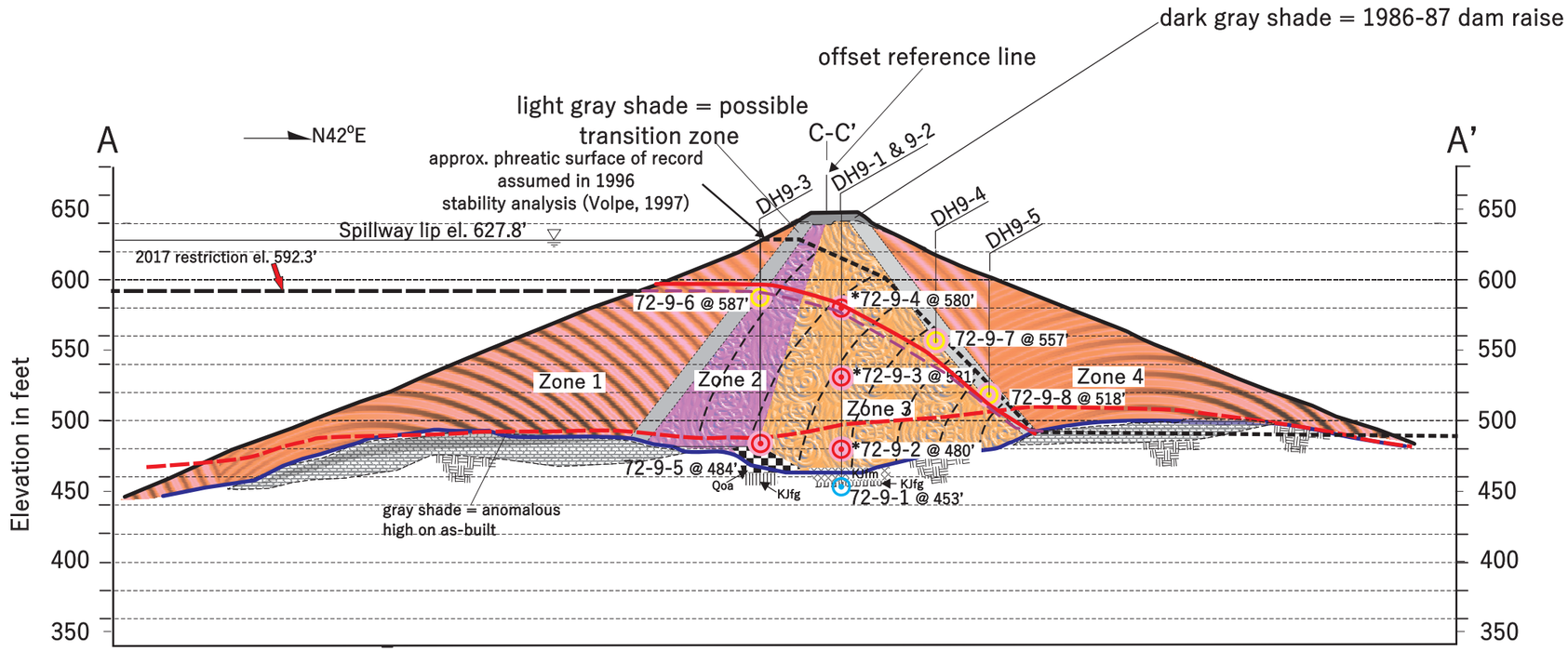
Santa Clara Valley Water District

Topographic Map Surveillance Instrumentation Leroy Anderson Dam

SCALE 1" = 200'

PLATE 1

Section A-A' (sta. 6+00)



Explanation

DH9-5 boring number

72-9-8 vibrating wire piezometer

excavated topography (as-built) adjusted to DIP drill hole logs

excavated topography (as-built) corrected 2.8' for new datum

original topography corrected 2.8' for new datum

* = installed using grout-in methods (see Nelson, 2009b)
all other piezometers installed using sand-pack methods

Embankment/Fill Units from DIP/SSE1A

- Zones 1 (downstream) and 4 (upstream): rockfill
- Transition Zones, downstream and upstream
- Zone 2 upstream core
- Zone 3 downstream core

Bedrock & Soil Foundation Units from DIP/SSE1B

- Qoa/Qc = Quaternary older alluvium and/or colluvium
- QTsc = Plio-Pleistocene Santa Clara Fm
- KJfm = Franciscan Complex melange
- KJfg = Franciscan Complex greenstone

- red = embankment
- yellow = transition zone
- green = colluvium/alluvium
- blue = foundation

Phreatic Surfaces & Equipotential Lines

- Phreatic surface of record Volpe, 1997
- Phreatic surface Action Level - tied to 2017 res. restriction
- 2018 maximum excursion embankment piezometers
- approx. equipotential lines (GEI, 2009)

Notes:
1) File: W:\geology\dams\Historic_Dam_Geology\Anderson\andxsecA-A'2018.cdr
2) basis of elevations is NAVD 1988-elevations are 2.80' higher than NGVD 1929

DATE	01/09/19
DESIGN	JLN
DRAWN	JLN
CHECKED	MRM

Santa Clara Valley Water District

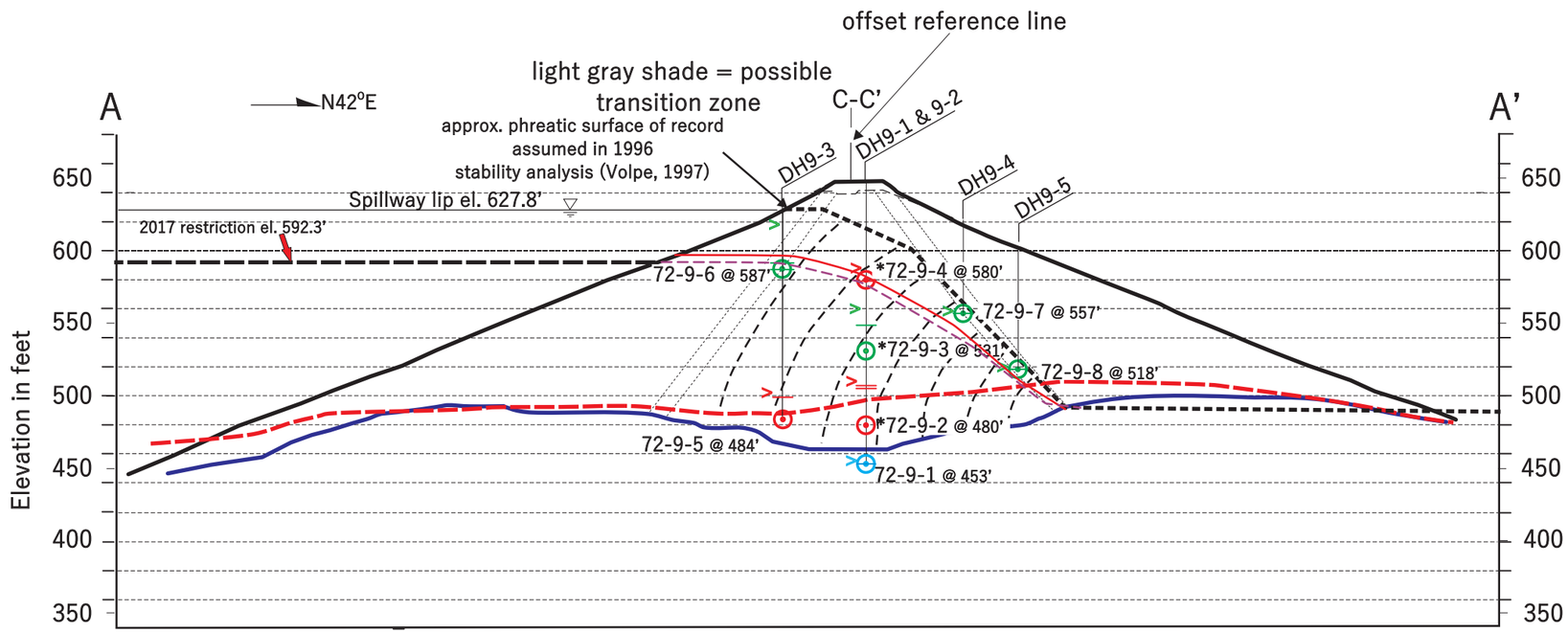
Cross Section A-A'

Leroy Anderson Dam

SCALE 1"=100'

PLATE 2

Section A-A' (sta. 6+00)



Explanation

DH9-5 boring number

72-9-8 vibrating wire piezometer

excavated topography (as-built) adjusted to DIP drill hole logs

original topography corrected 2.8' for new datum

* = installed using grout-in methods (see Nelson, 2009b)
all other piezometers installed using sand-pack methods

Phreatic Surfaces & Equipotential Lines

Phreatic surface of record AMEC, 2012

Phreatic surface Action Level - tied to 2011 res. restriction

Piezometer Metrics

Different colors are used to match piezometers with metrics. Red circle pairs with red arrowhead and horizontal lines.

> Arrowhead = Piezometer max
— Horizontal lines = Annual max/min

Notes:
1) File: W:\geology\dams\Historic_Dam_Geology\Anderson\andxsecA-A'2018Hilo.cdr
2) basis of elevations is NAVD 1988-elevations are 2.80' higher than NGVD 1929

DATE	01/09/19
DESIGN	HM
DRAWN	HM
CHECKED	MRM

Santa Clara Valley Water District

Cross Section A-A'

Piezometer Metrics

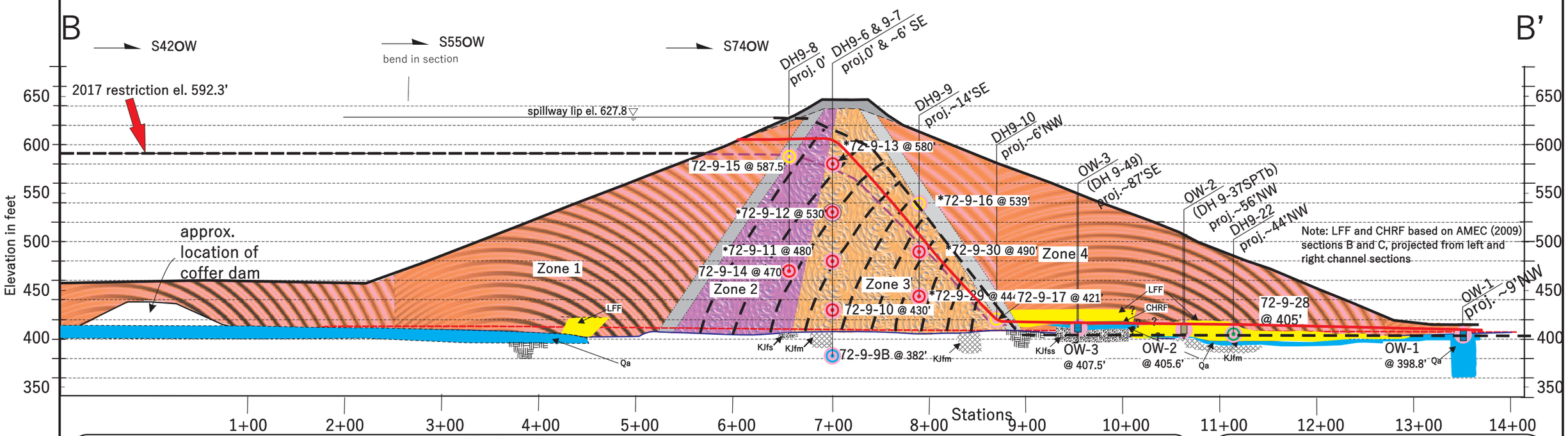
Maximum and Annual Range

Leroy Anderson Dam

SCALE 1"=100'

PLATE 3

Section B-B' (transverse max section along thalweg)



Explanation

boring number DH9-22

72-9-28 vibrating wire piezometer

open well & pneumatic piezometers

DH9-20 geophysical

DH9-20 lithologic logging

excavated topography (as-built) corrected 2.8' for new datum

original topography corrected 2.8' for new datum

excavated topography (as-built) adjusted to DIP drill hole logs

* = installed using grout-in methods (see Nelson, 2009b)

all other piezometers installed using sand-pack methods

Embankment/Fill Units from DIP/SSE1A

- Zones 1 (downstream) and 4 (upstream): rockfill
- Transition Zones, downstream and upstream
- Zone 2 upstream core
- Zone 3 downstream core
- Construction haul road fill (CHRF)
- Lower Finer Fill (LLF), downstream and upstream

red = embankment
yellow = transition zone
green = colluvium/alluvium
blue = foundation

lower finer fill (LFF)

Bedrock and Foundation Soil Units from DIP/SSE1A

- Qa/Qc = Quaternary alluvium and/or colluvium
- KJfm = Franciscan Complex melange
- KJfss = Franciscan Complex graywacke sandstone

Phreatic Surfaces & Equipotential Lines

- Phreatic surface of record Volpe, 1997
- Phreatic surface Upper Action Level - tied to 2017 res. restriction
- 2018 maximum excursion embankment piezometers
- approx. equipotential lines (GEI, 2009)

Notes:
1) File: W:\geology\dams\historic dam geology\anderson\andxsecB-B'2018.cdr
2) basis of elevations is NAVD 1988-elevations are 2.80' higher than NGVD 1929
3) Downstream and upstream foundation materials taken from AMEC (2010 draft)

DATE	01/11/19
DESIGN	JLN
DRAWN	JLN
CHECKED	MRM

Santa Clara Valley Water District

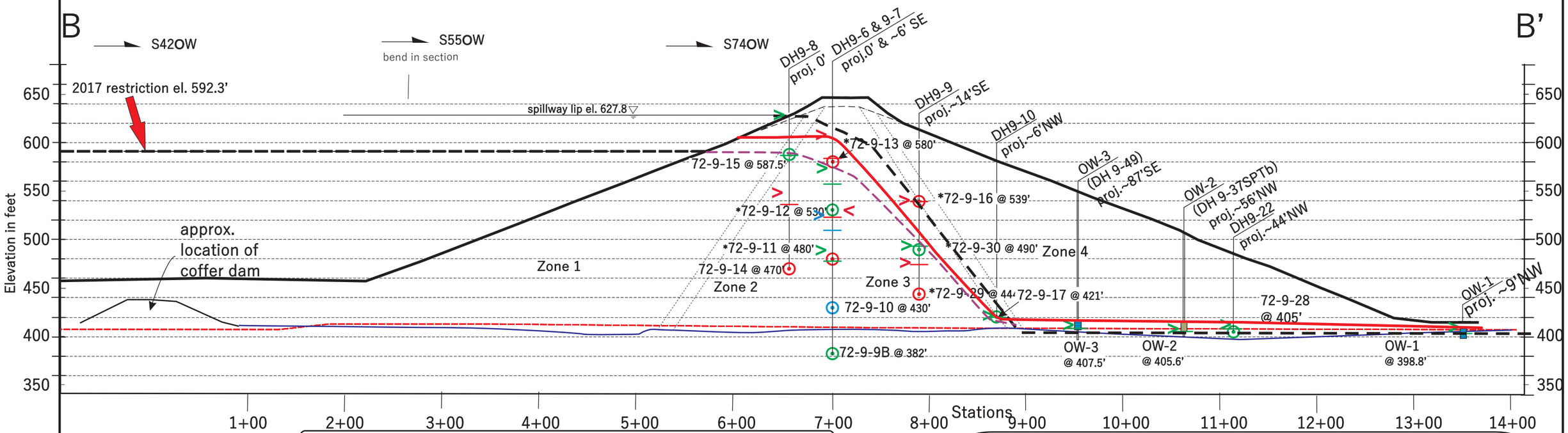
DAM SAFETY PROGRAM

Anderson Dam 72-9
Cross Section B-B'

SCALE 1"=100'

PLATE 4

Section B-B' (transverse max section along thalweg)



Explanation

boring number DH9-22

72-9-28 vibrating wire piezometer
open well &
pneumatic piezometers

DH9-20 geophysical

DH9-20 lithologic logging

original topography corrected 2.8' for new datum

excavated topography (as-built) adjusted to DIP drill hole logs

* = installed using grout-in methods (see Nelson, 2009b)
all other piezometers installed using sand-pack methods

Phreatic Surfaces & Equipotential Lines

Phreatic surface of record Volpe, 1997

Phreatic surface Upper Action Level - tied to 2017 res. restriction

2018 maximum excursion embankment piezometers

Piezometer Metrics

Different colors are used to match piezometers with metrics. Red circle pairs with red arrowhead and horizontal lines.

> Arrowhead = Piezometer max
Horizontal lines = Annual max/min

Notes:
1) File: W:\geology\dams\historic dam geology\anderson\andxsecB-B'2018Hilo.cdr
2) basis of elevations is NAVD 1988-elevations are 2.80' higher than NGVD 1929
3) Downstream and upstream foundation materials taken from AMEC (2010 draft)

DATE	01/11/19
DESIGN	JLN
DRAWN	JLN
CHECKED	MRM

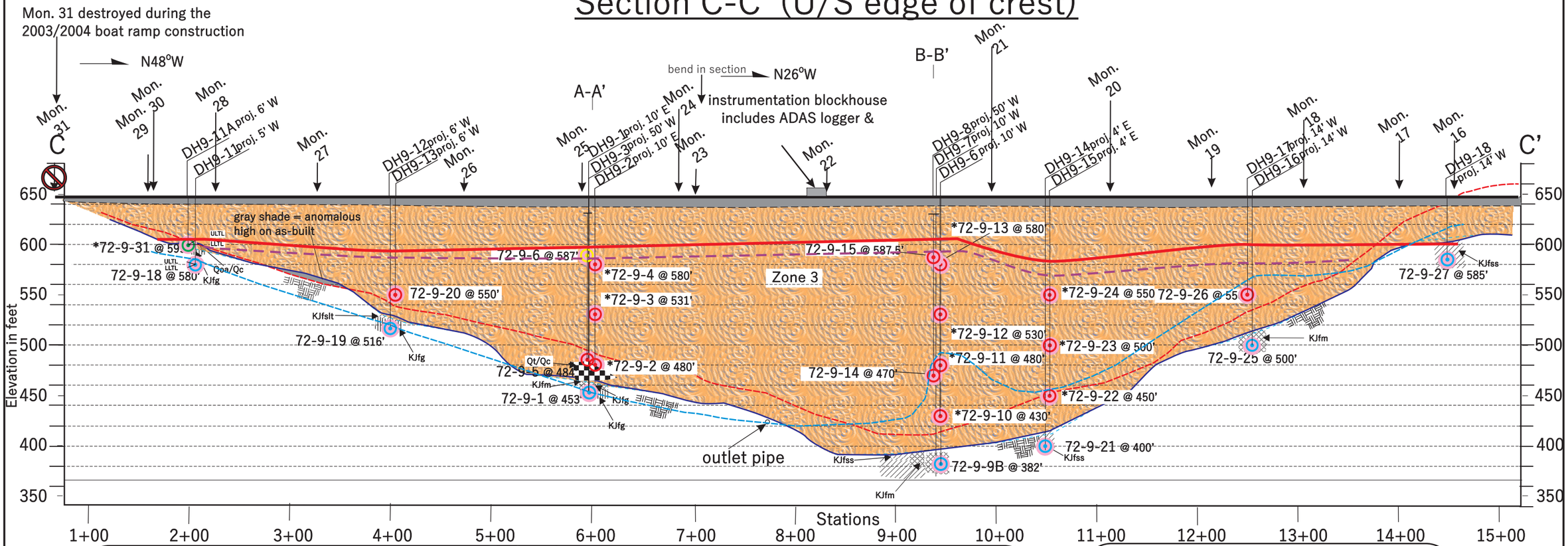
Santa Clara Valley Water District

Cross Section B-B'
Piezometer Metrics
Maximum and Annual Range
Leroy Anderson Dam

SCALE 1"=100'

PLATE 5

Section C-C' (U/S edge of crest)



Explanation

boring number DH9-18

72-9-27 vibrating wire piezometer

open well & pneumatic piezometers

DH9-20 geophysical/ lithologic logging

excavated topography (as-built) corrected 2.8' for new datum

original topography corrected 2.8' for new datum

excavated topography (as-built) adjusted to DIP drill hole logs

* = installed using grout-in methods (see Nelson, 2009b)
all other piezometers installed using sand-pack methods

Embankment/Fill Units

Zone 3 downstream core

Bedrock and Foundation Soil Units from DIP

Qoa/Qc = Quaternary older alluvium and/or colluvium

KJfm = Franciscan Complex melange

KJfg = Franciscan Complex greenstone

KJfss = Franciscan Complex sandstone

red = embankment
yellow = transition zone
green = colluvium/alluvium
blue = foundation

Phreatic Surfaces

Phreatic surface Action Level - tied to 2017 res. restriction

2018 maximum excursion embankment piezometers

2018 maximum excursion foundation piezometers

Notes:
1) File: W:\Geology\DAMS\Historic_Dam_Geology\Anderson\andxsecC-C'2018.cdr
2) basis of elevations is NAVD 1988-elevations are 2.80' higher than NGVD 1929

DATE	01/14/19
DESIGN	JLN
DRAWN	JLN
CHECKED	MRM

Santa Clara Valley Water District

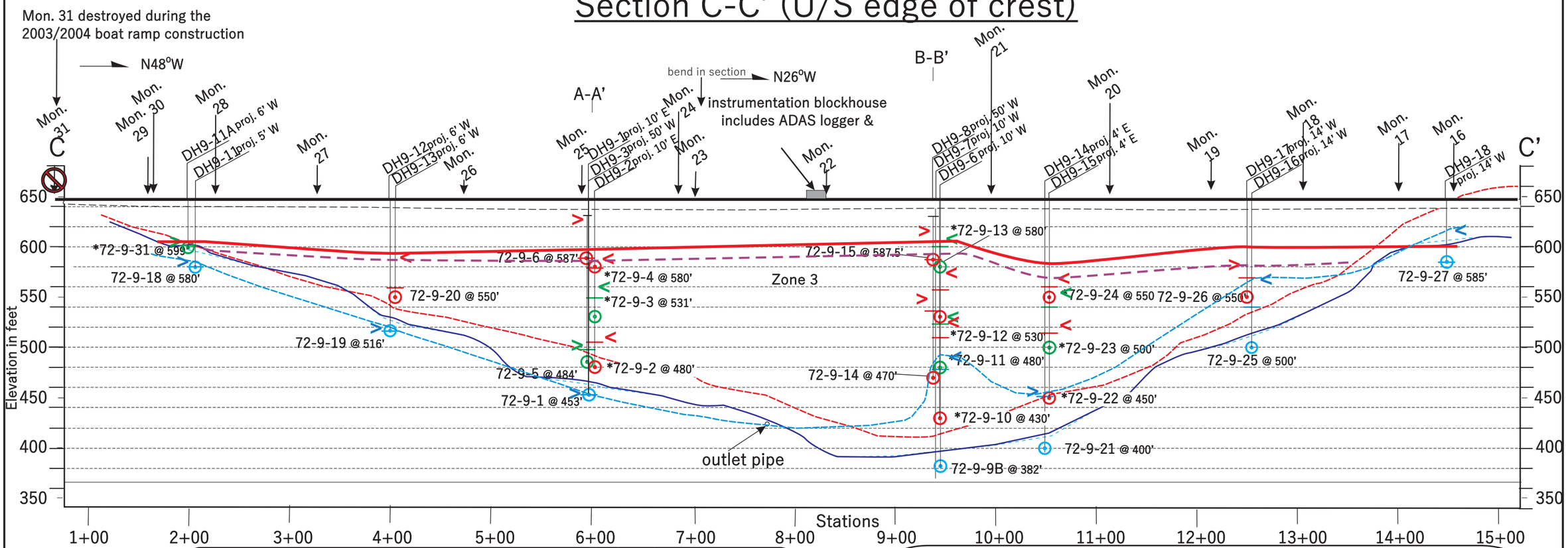
Longitudinal Cross Section C-C'

Leroy Anderson Dam

SCALE 1"=100'

PLATE 6

Section C-C' (U/S edge of crest)



Explanation

boring number DH9-18

72-9-27 vibrating wire piezometer

DH9-20 geophysical/ lithologic logging

open well & pneumatic piezometers

excavated topography (as-built) corrected 2.8' for new datum

original topography corrected 2.8' for new datum

excavated topography (as-built) adjusted to DIP drill hole logs

* = installed using grout-in methods (see Nelson, 2009b)

all other piezometers installed using sand-pack methods

Phreatic Surfaces

Phreatic surface Action Level - tied to 2017 res. restriction

2018 maximum excursion embankment piezometers

2018 maximum excursion foundation piezometers

Piezometer Metrics

Different colors are used to match piezometers with metrics. Red circle pairs with red arrowhead and horizontal lines.

> Arrowhead = Piezometer max

Horizontal lines = Annual max/min

Notes:

1) File: W:\Geology\DAMS\Historic_Dam_Geology\Anderson\andxsecC-C'2018Hilo.cdr

2) basis of elevations is NAVD 1988-elevations are 2.80' higher than NGVD 1929

DATE	01/14/19
DESIGN	JLN
DRAWN	JLN
CHECKED	MRM

Santa Clara Valley Water District

Longitudinal Cross Section C-C'

Piezometer Metrics

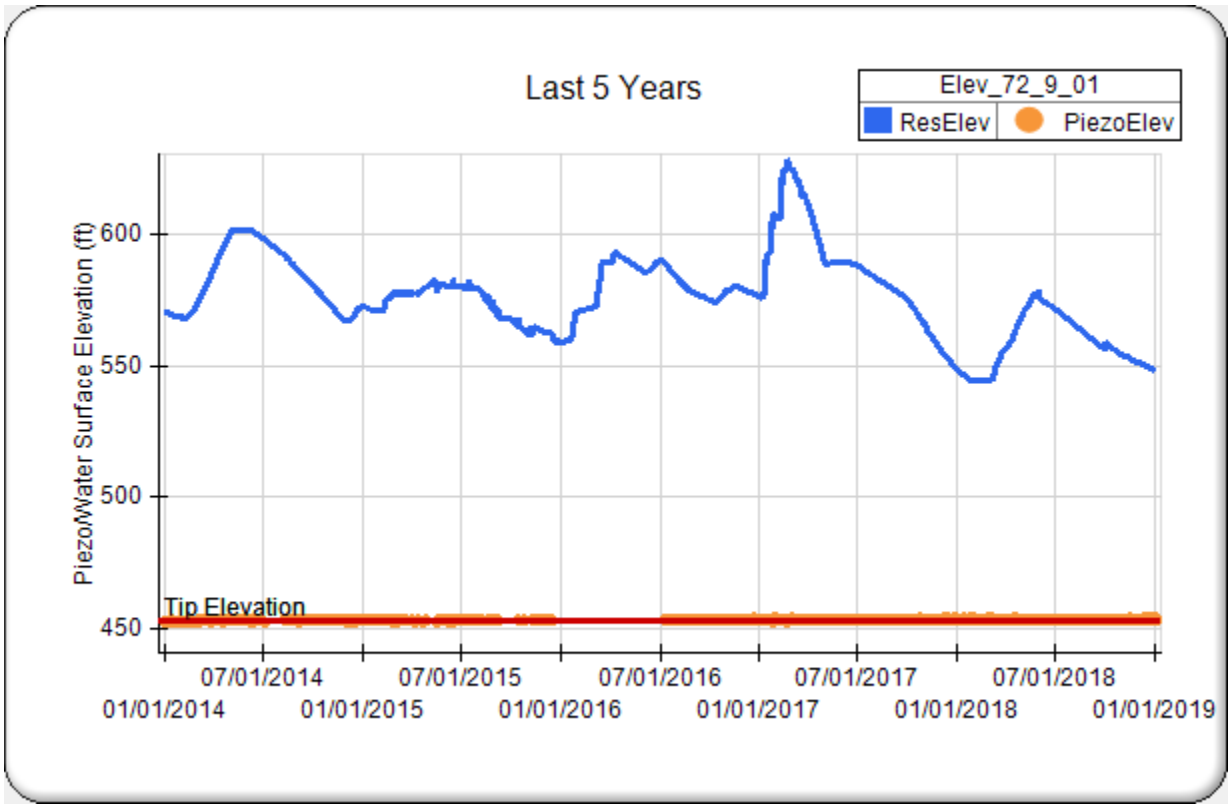
Maximum and Annual Range

Leroy Anderson Dam

SCALE 1"=100'

PLATE 7

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots



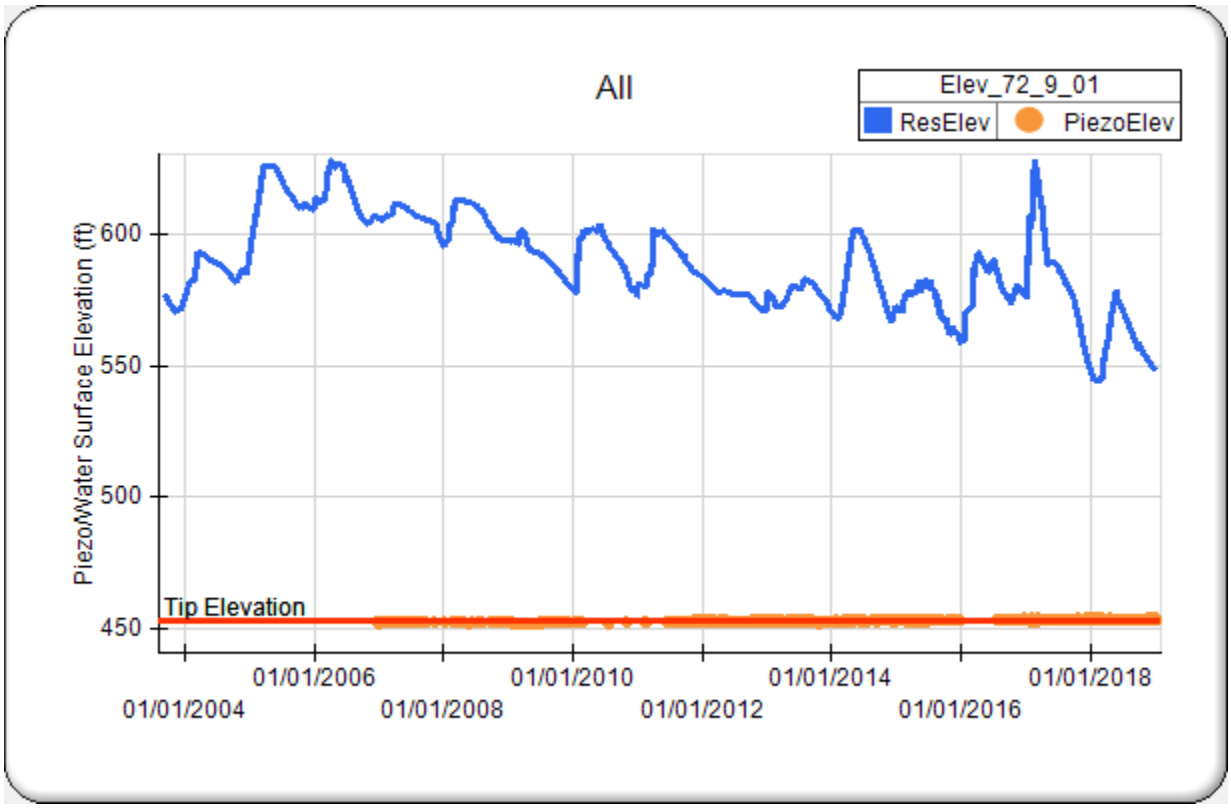
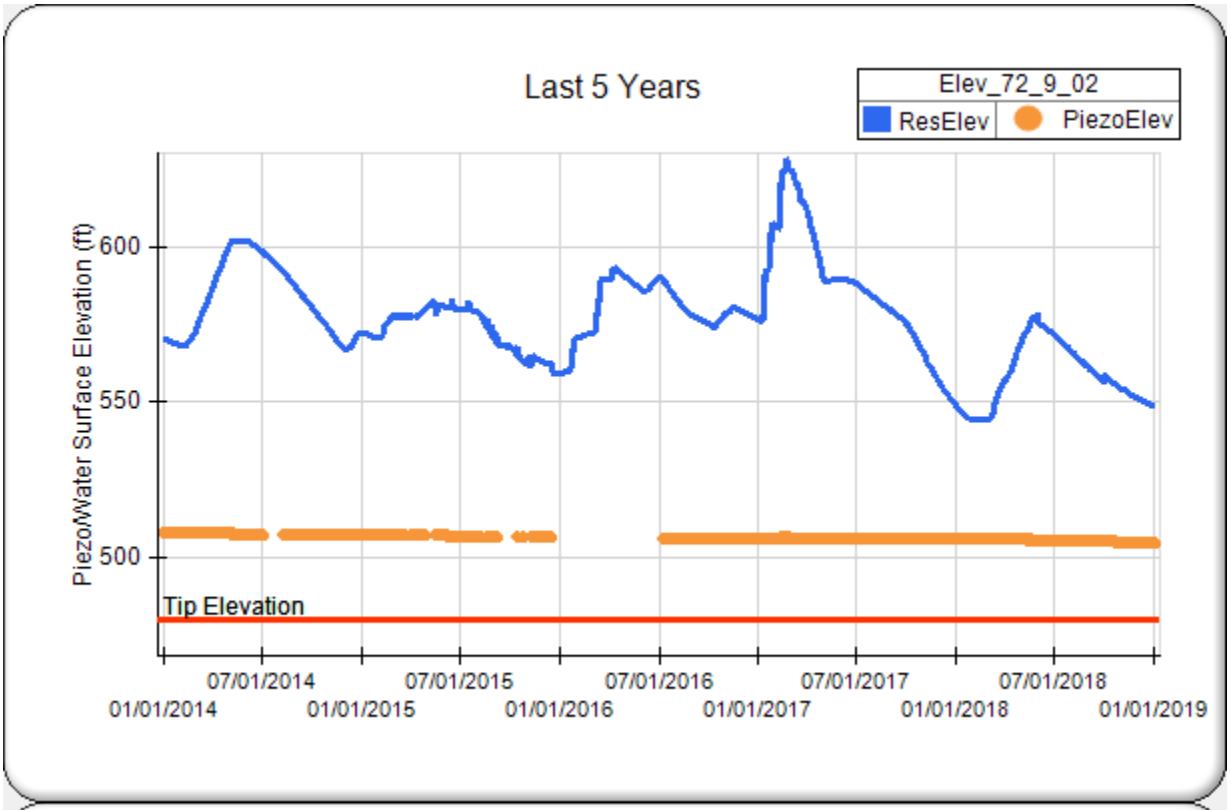


FIGURE 1-1

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots



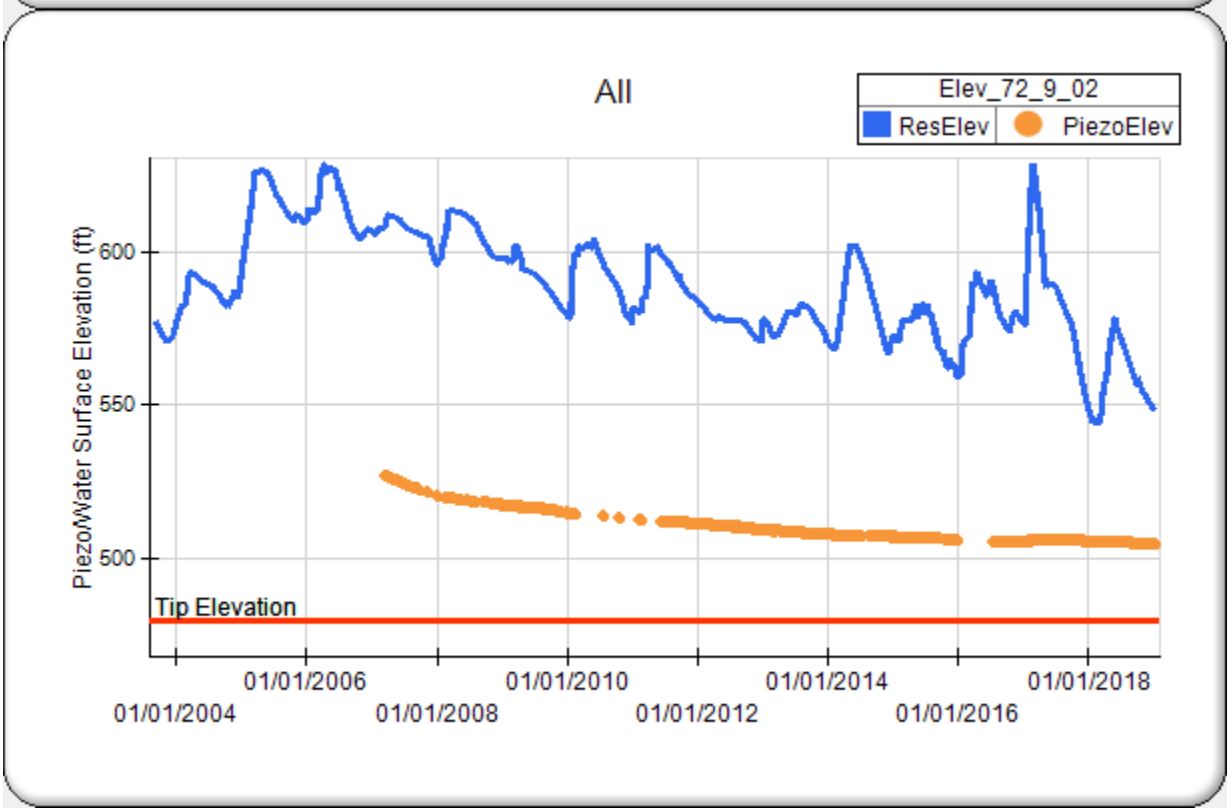


FIGURE 1-2

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

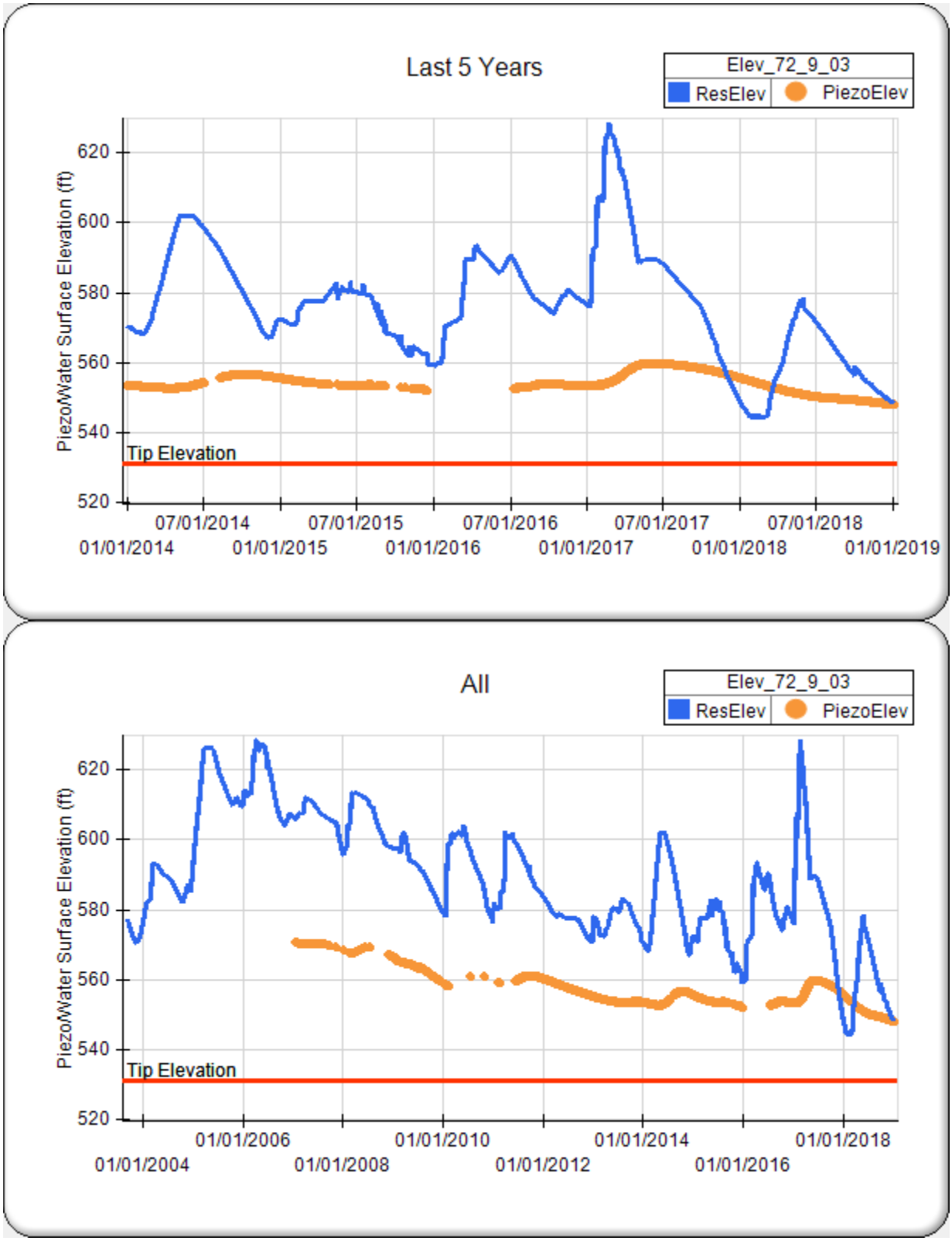


FIGURE 1-3

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

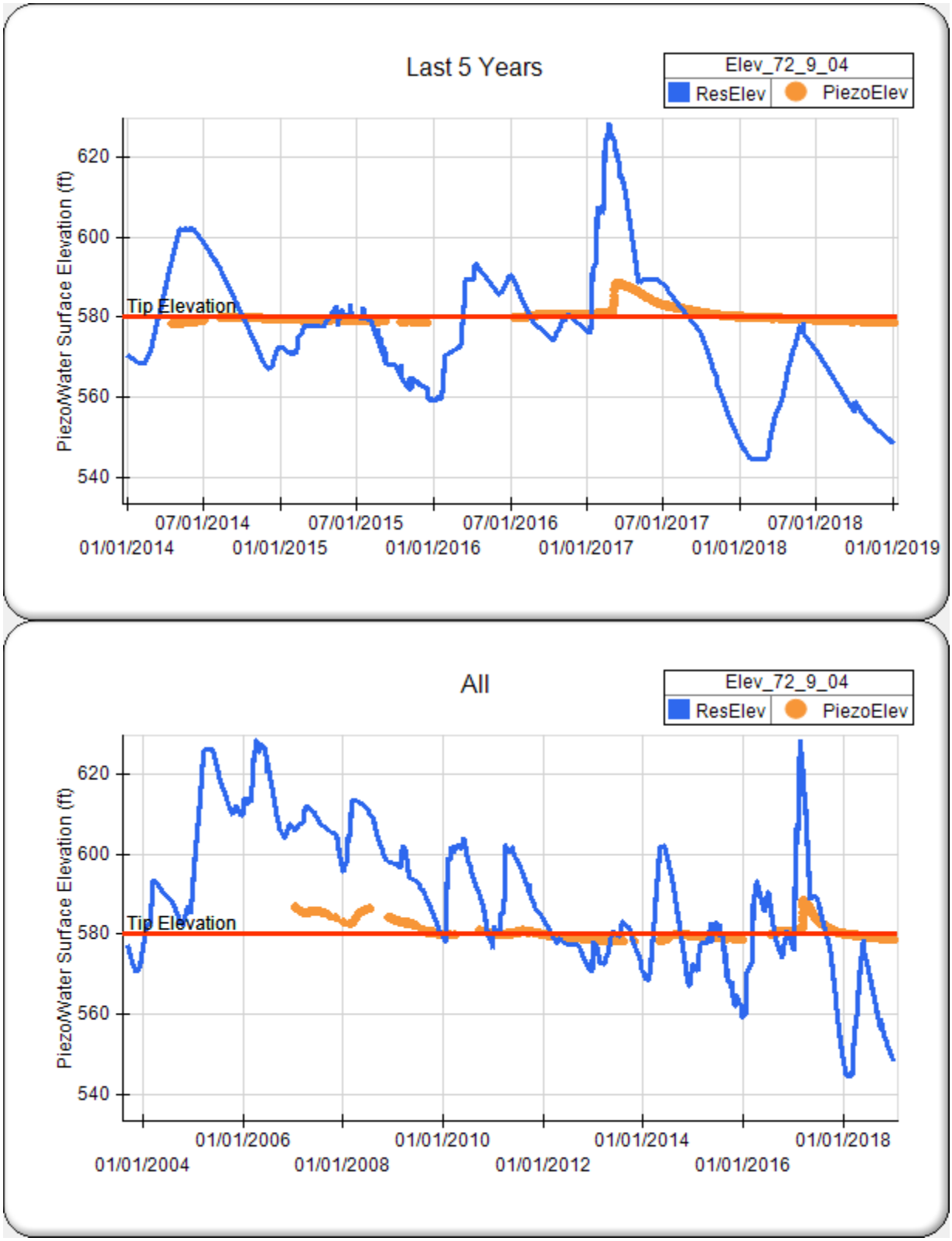


FIGURE 1-4

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

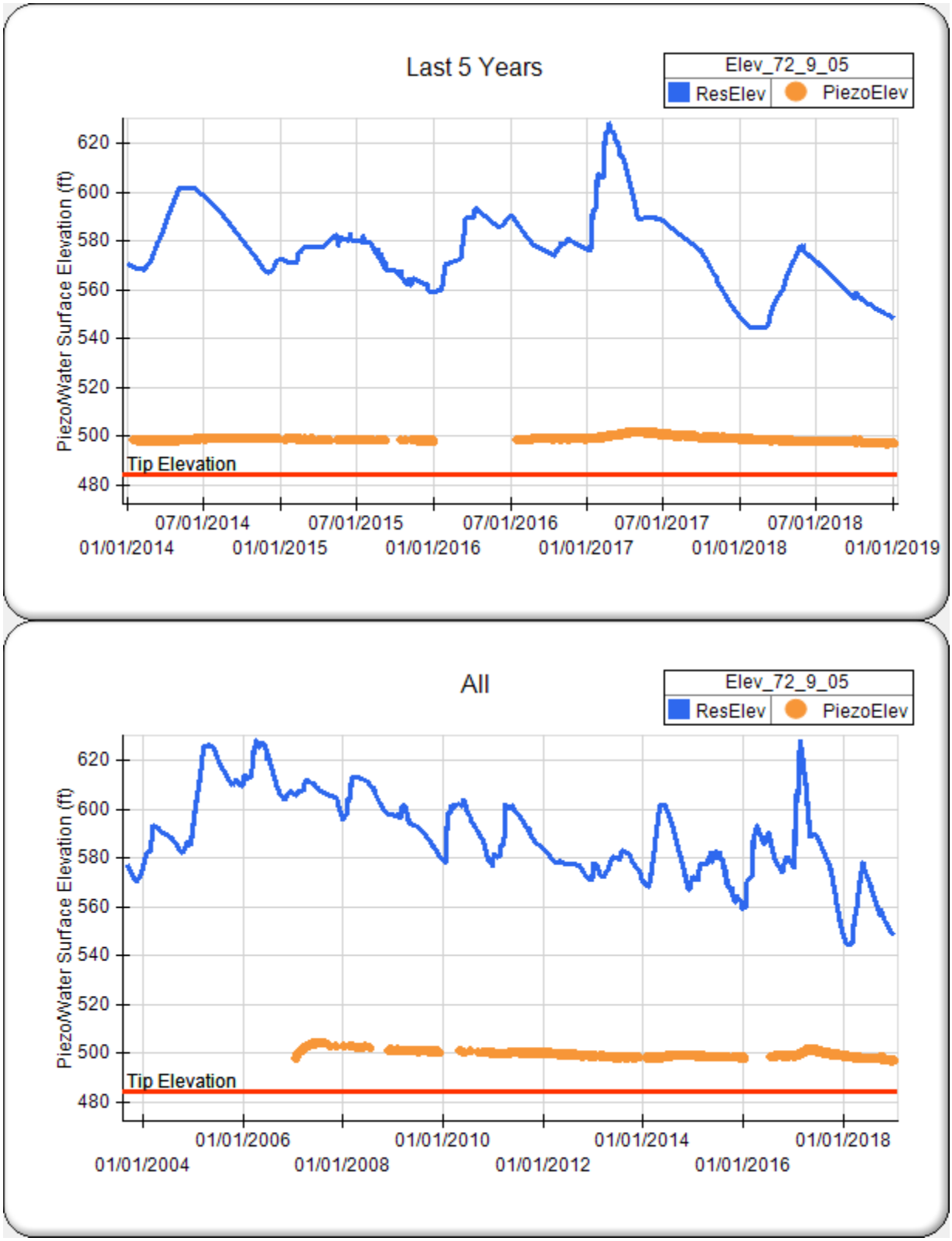


FIGURE 1-5

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

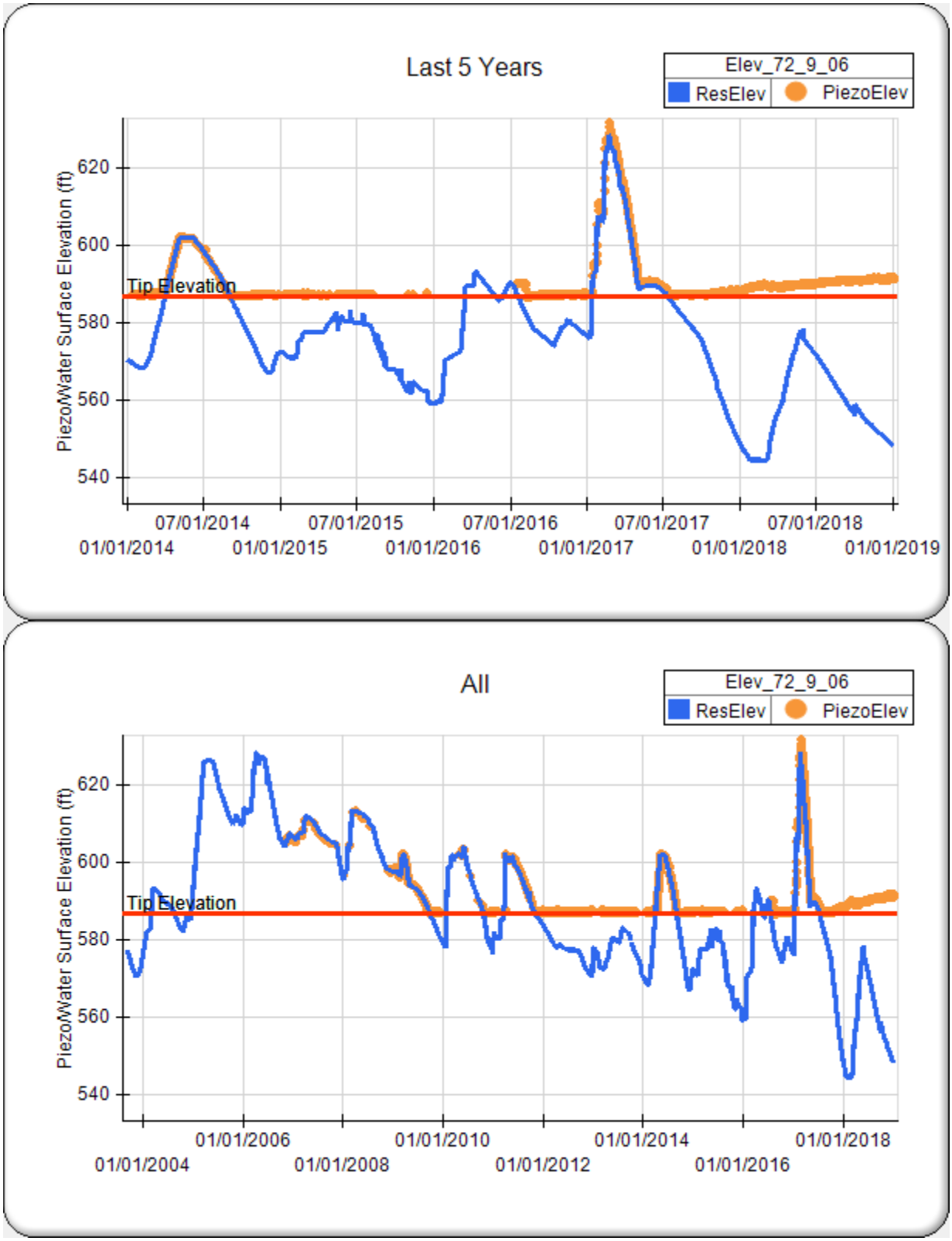


FIGURE 1-6

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

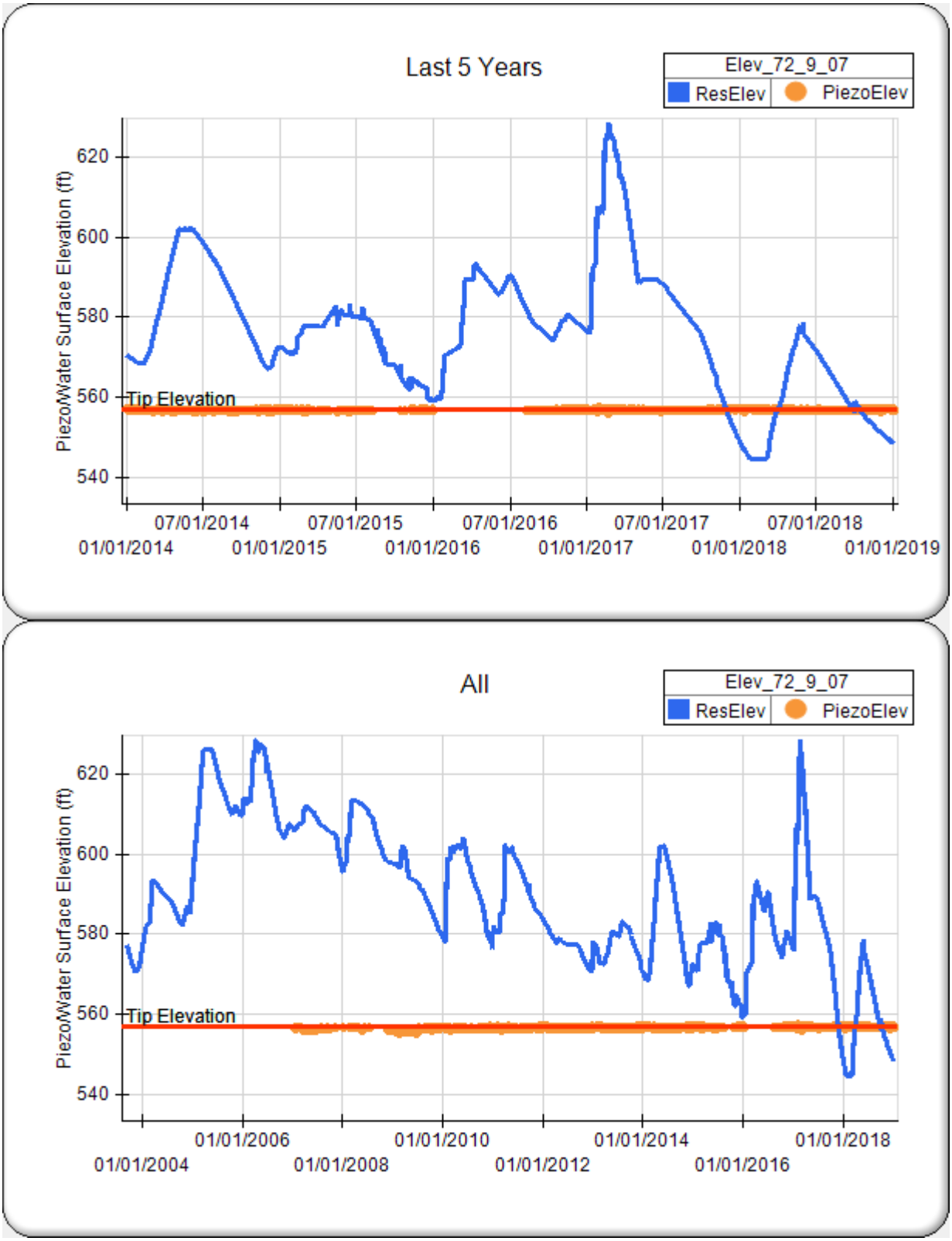


FIGURE 1-7

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

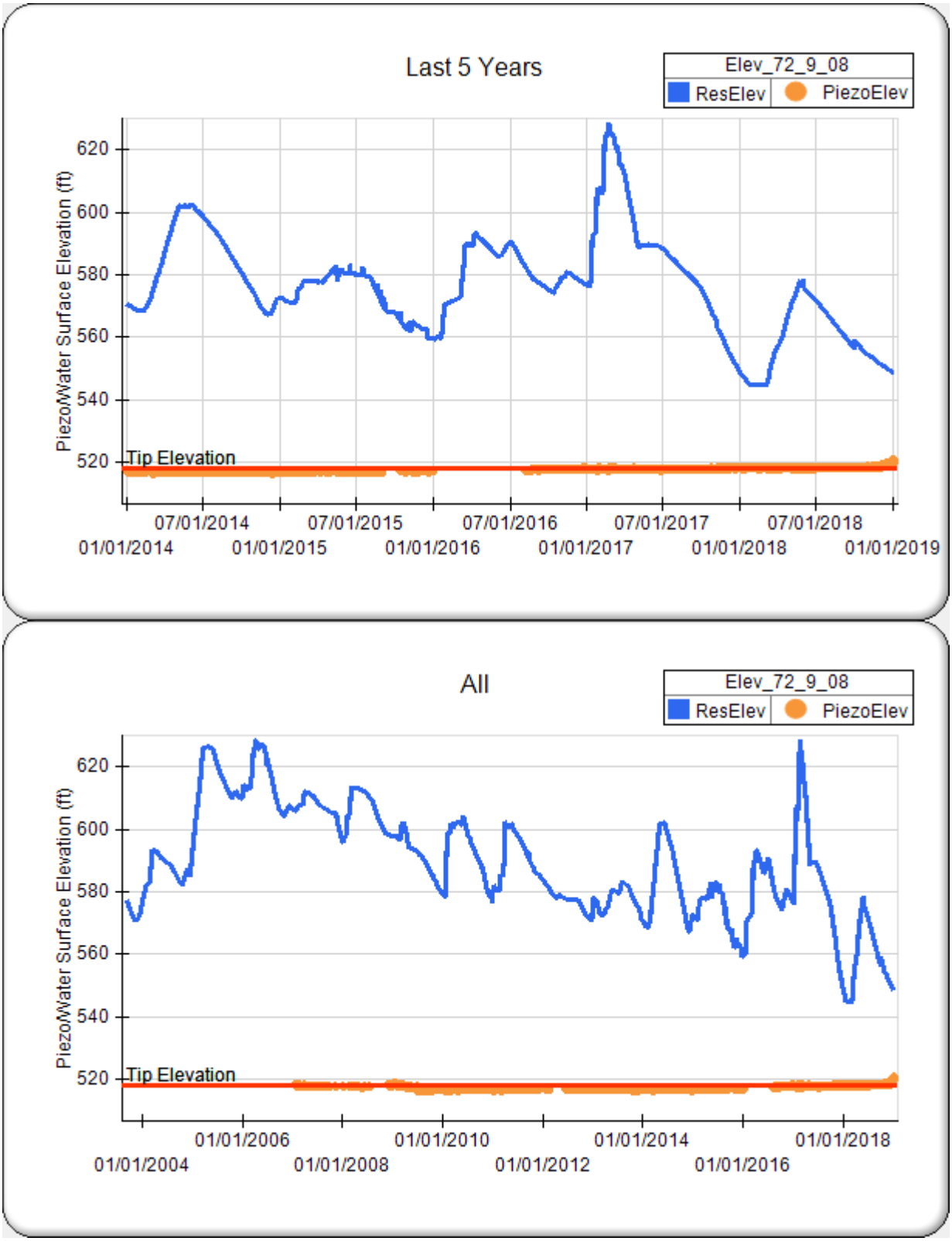


FIGURE 1-8

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

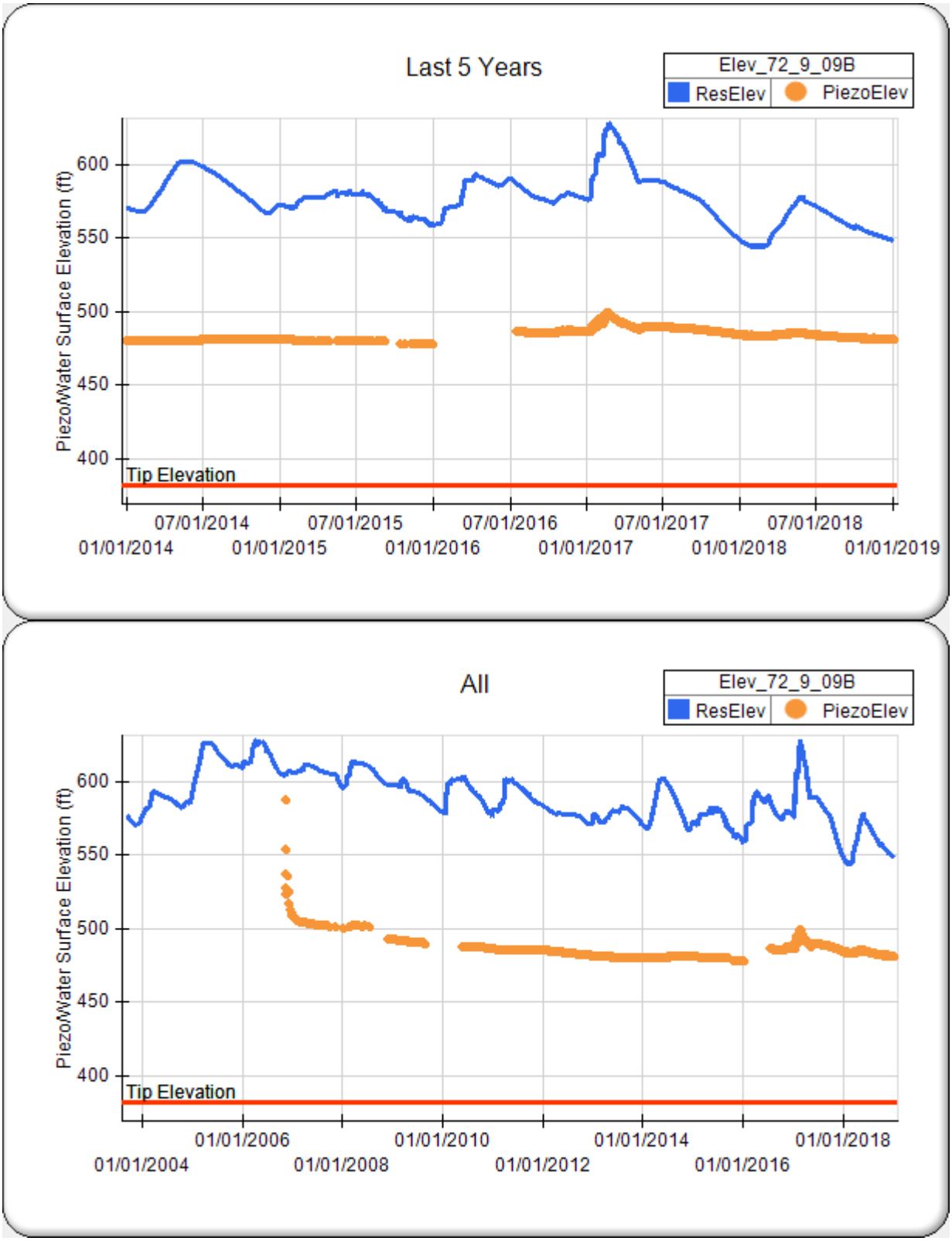


FIGURE 1-9

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

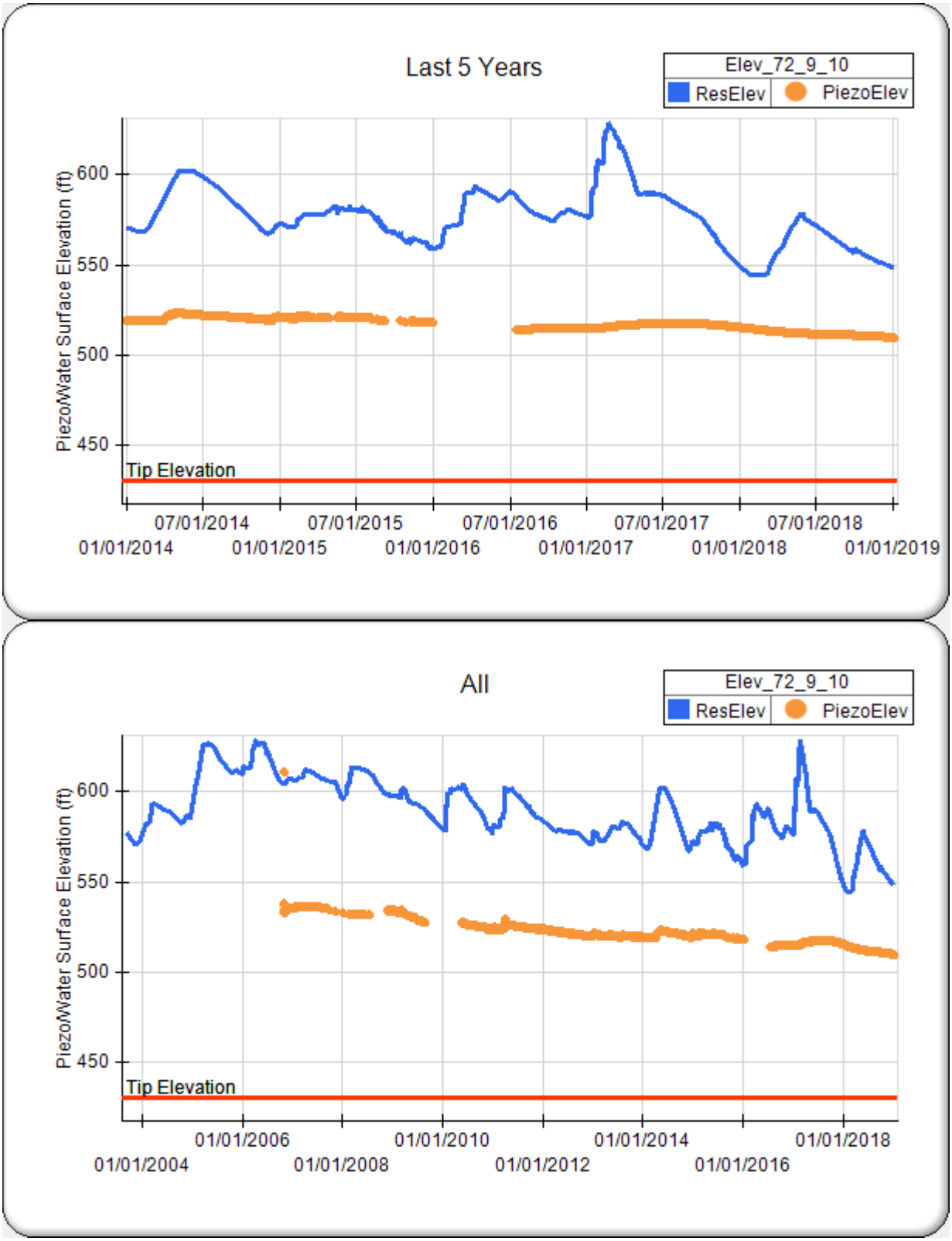


FIGURE 1-10

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

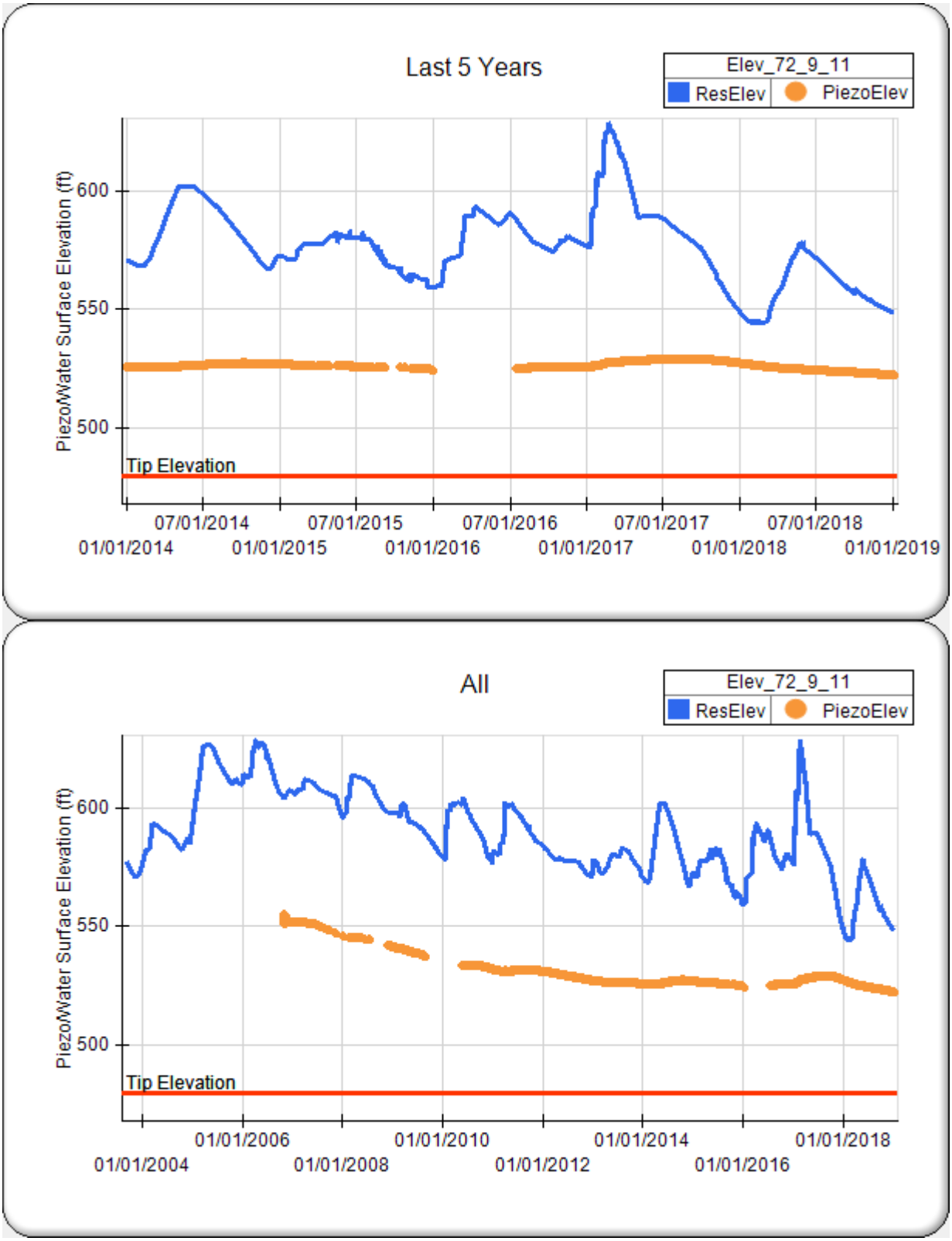
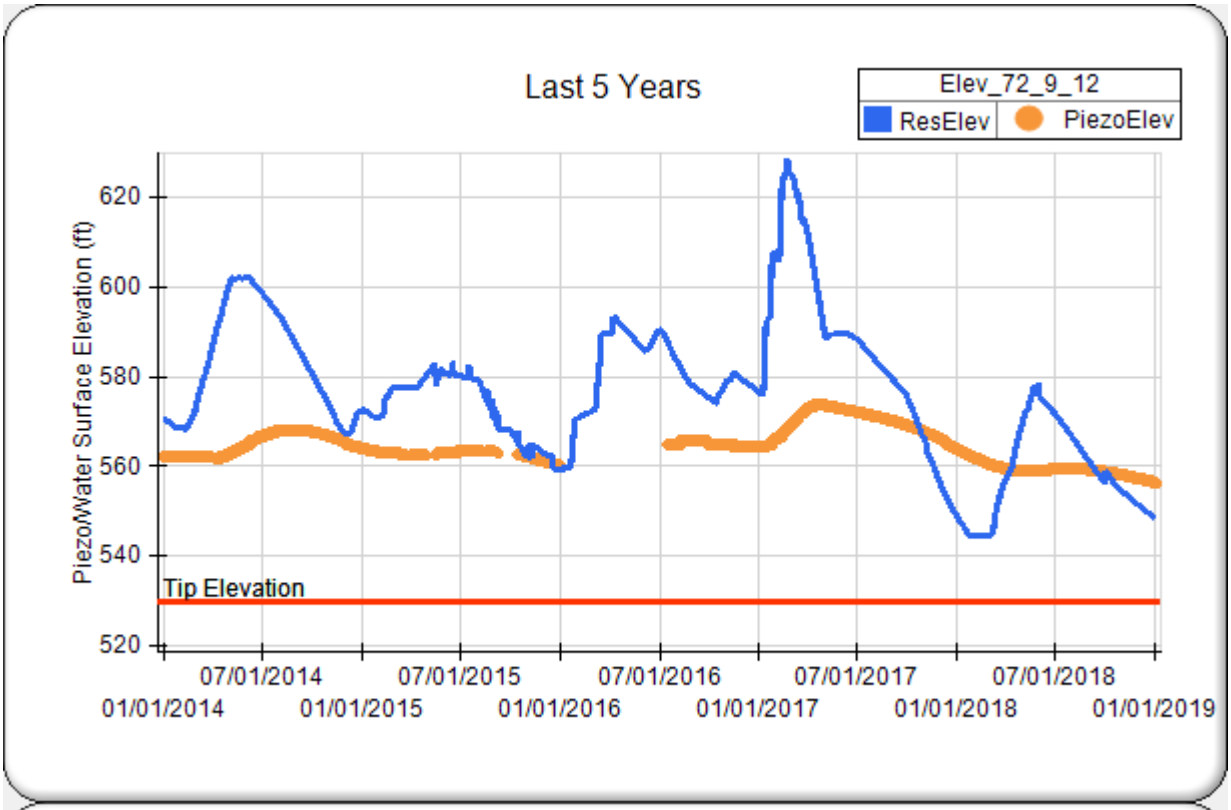


FIGURE 1-11

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots



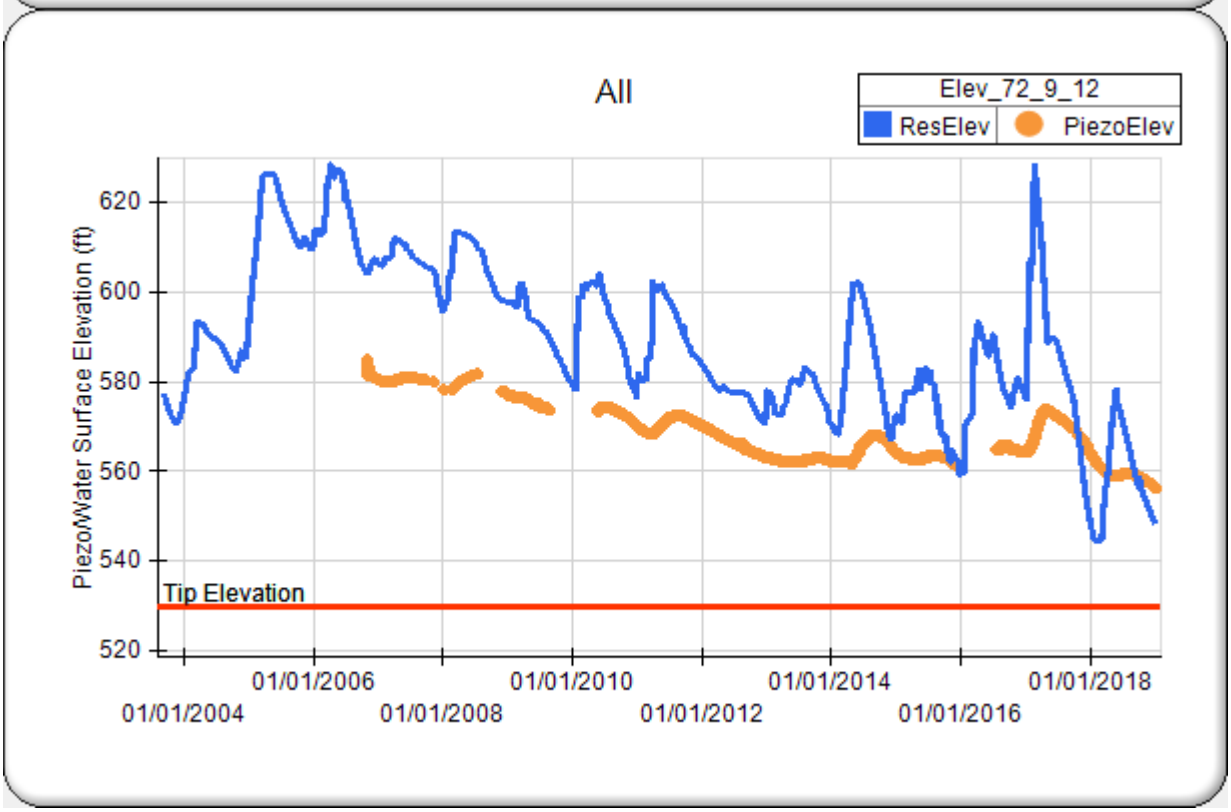


FIGURE 1-12

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

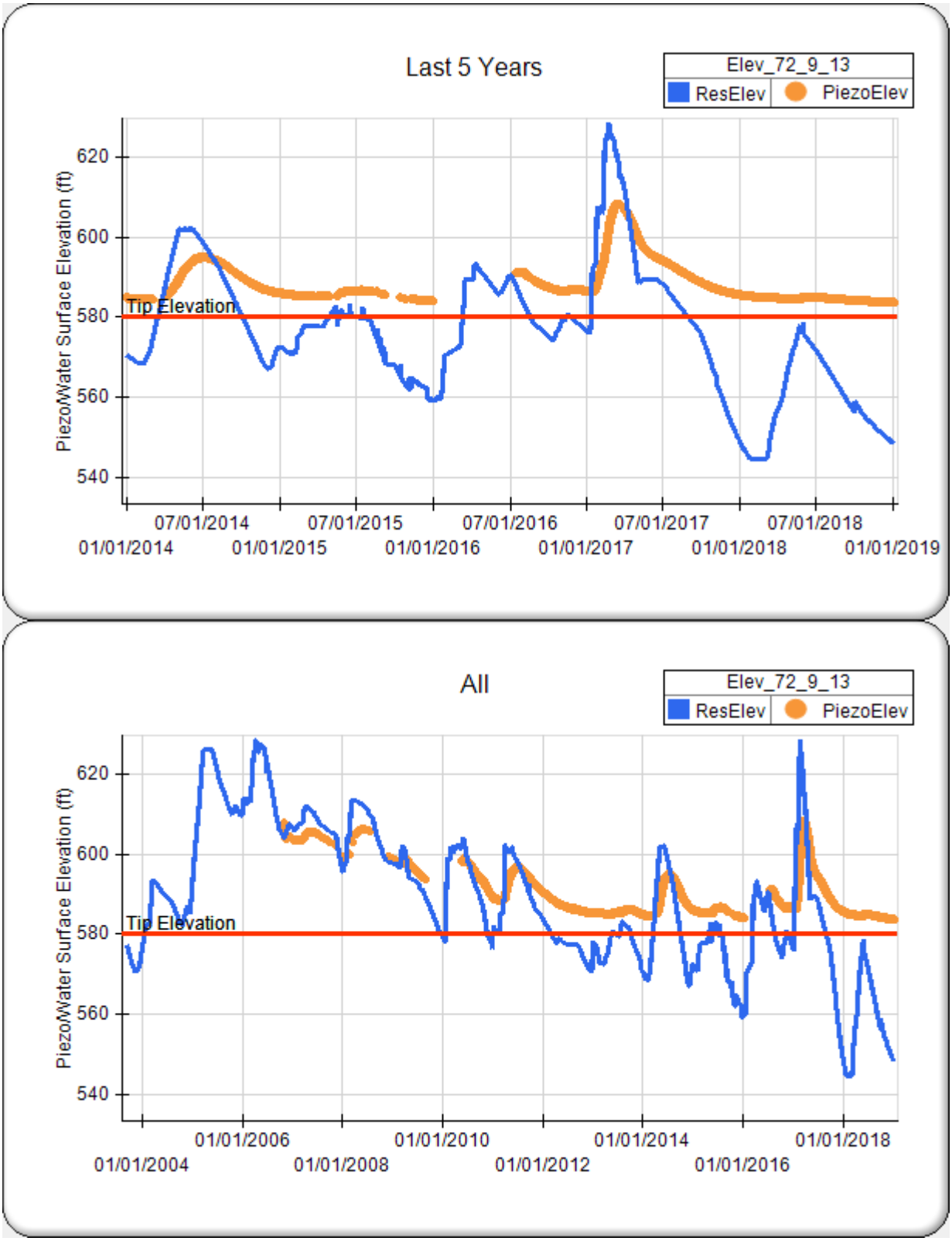


FIGURE 1-13

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

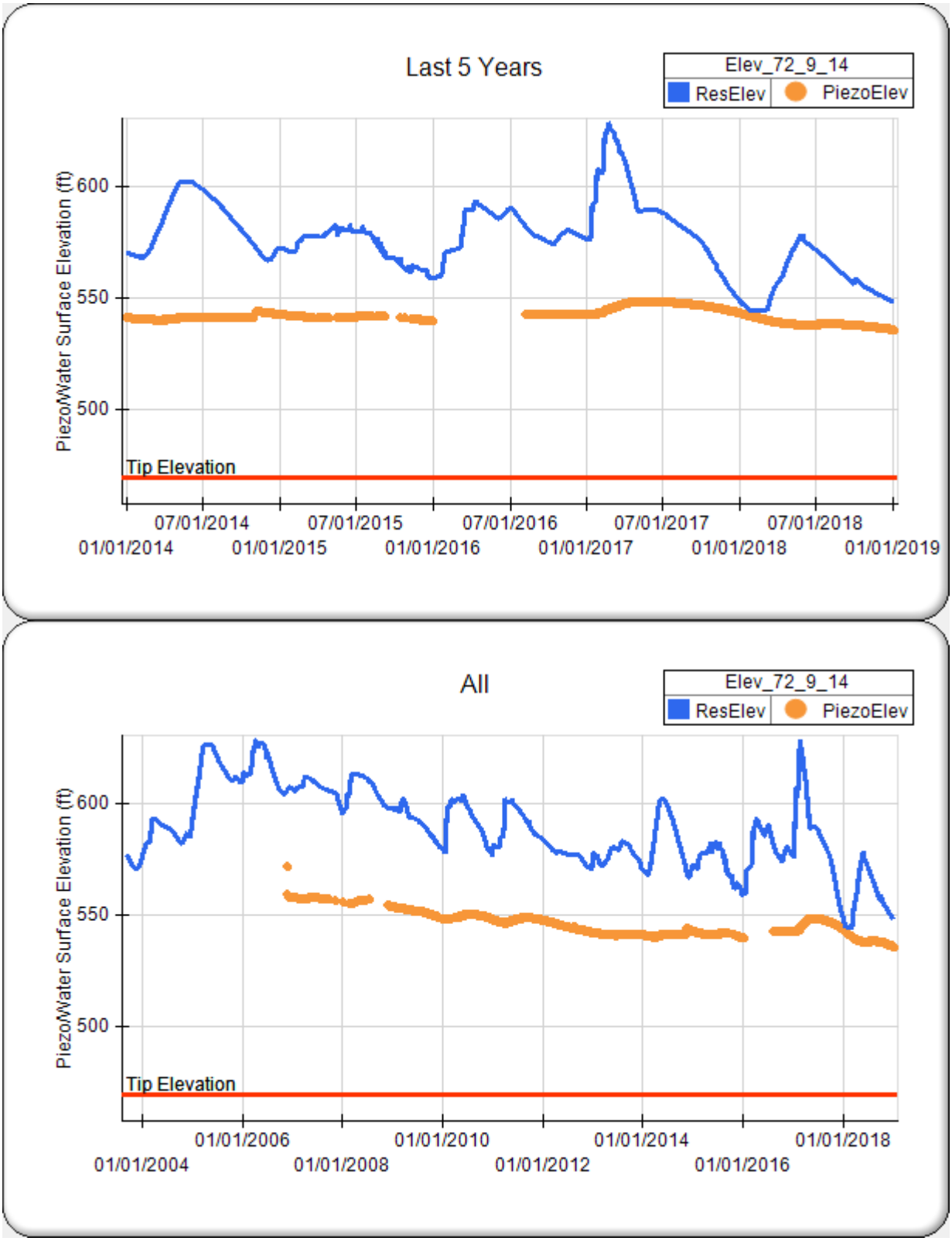


FIGURE 1-14

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

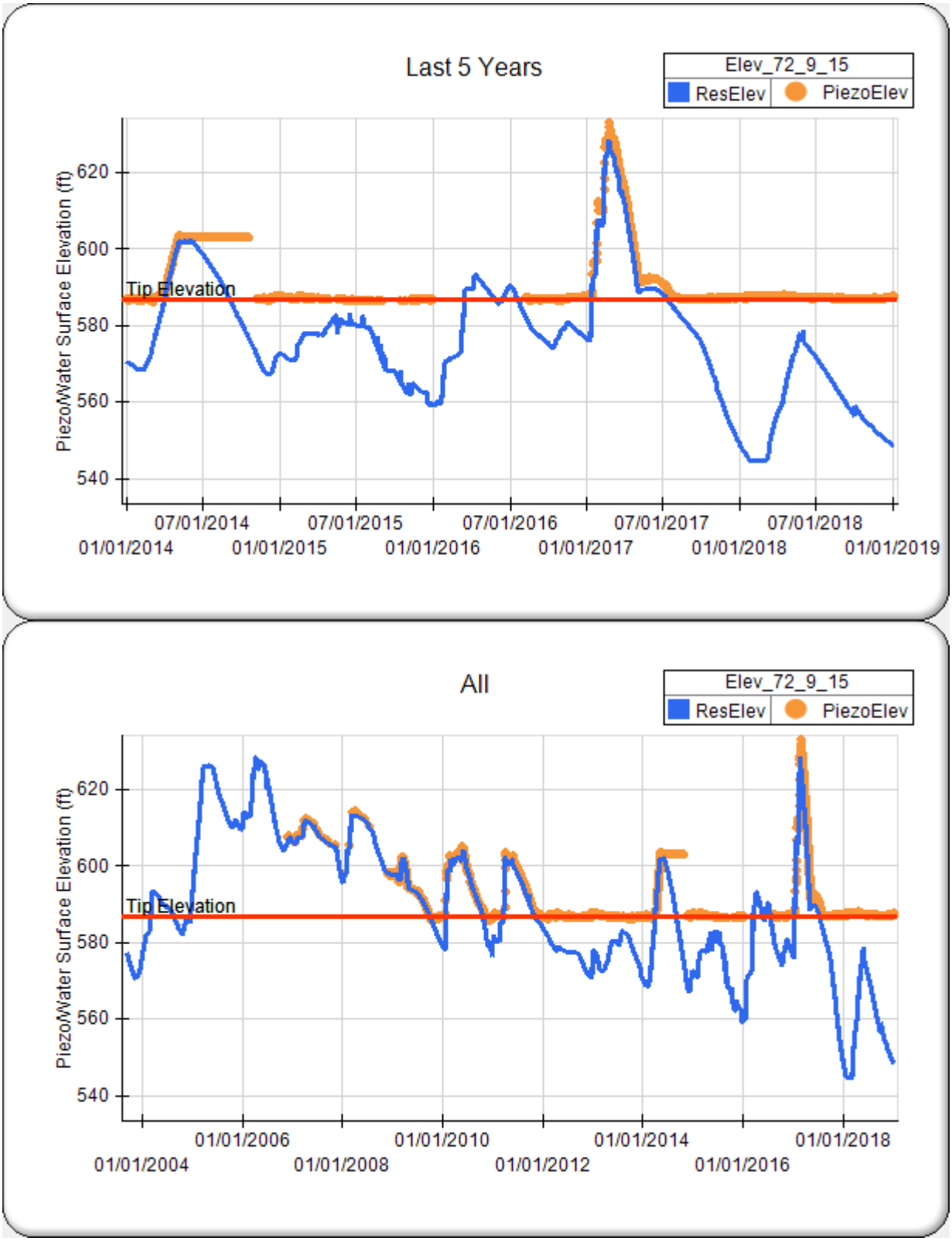


FIGURE 1-15

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

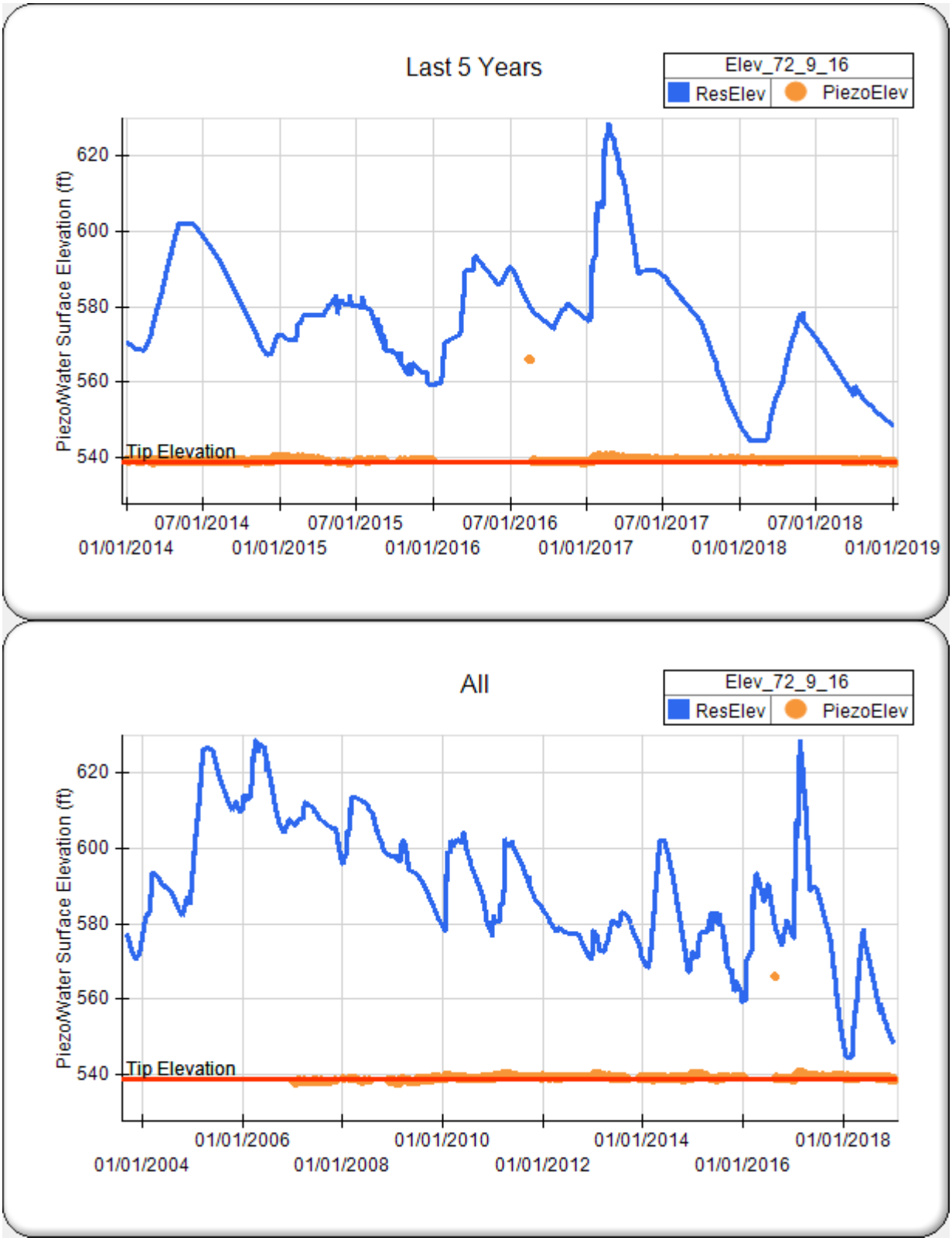


FIGURE 1-16

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

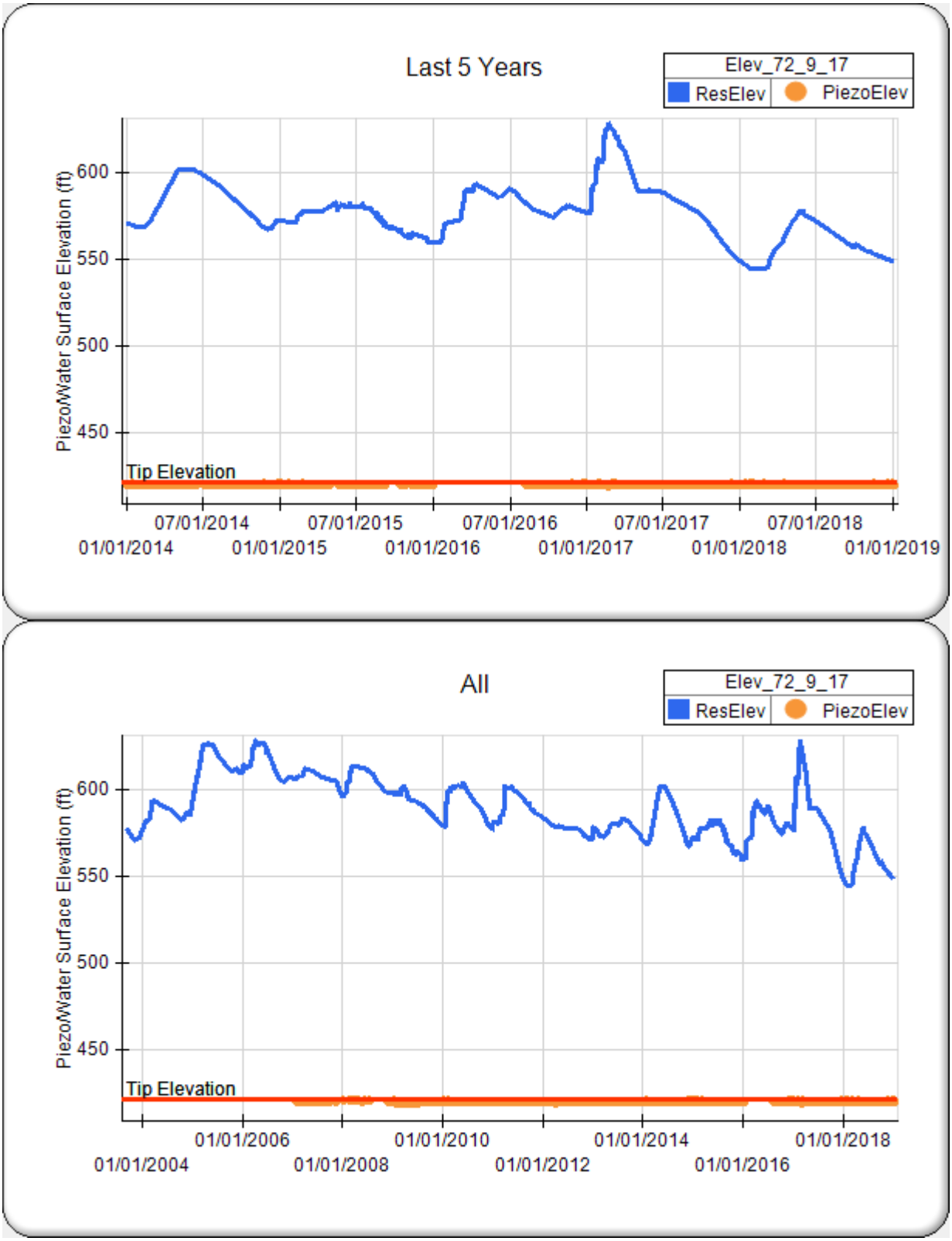


FIGURE 1-17

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

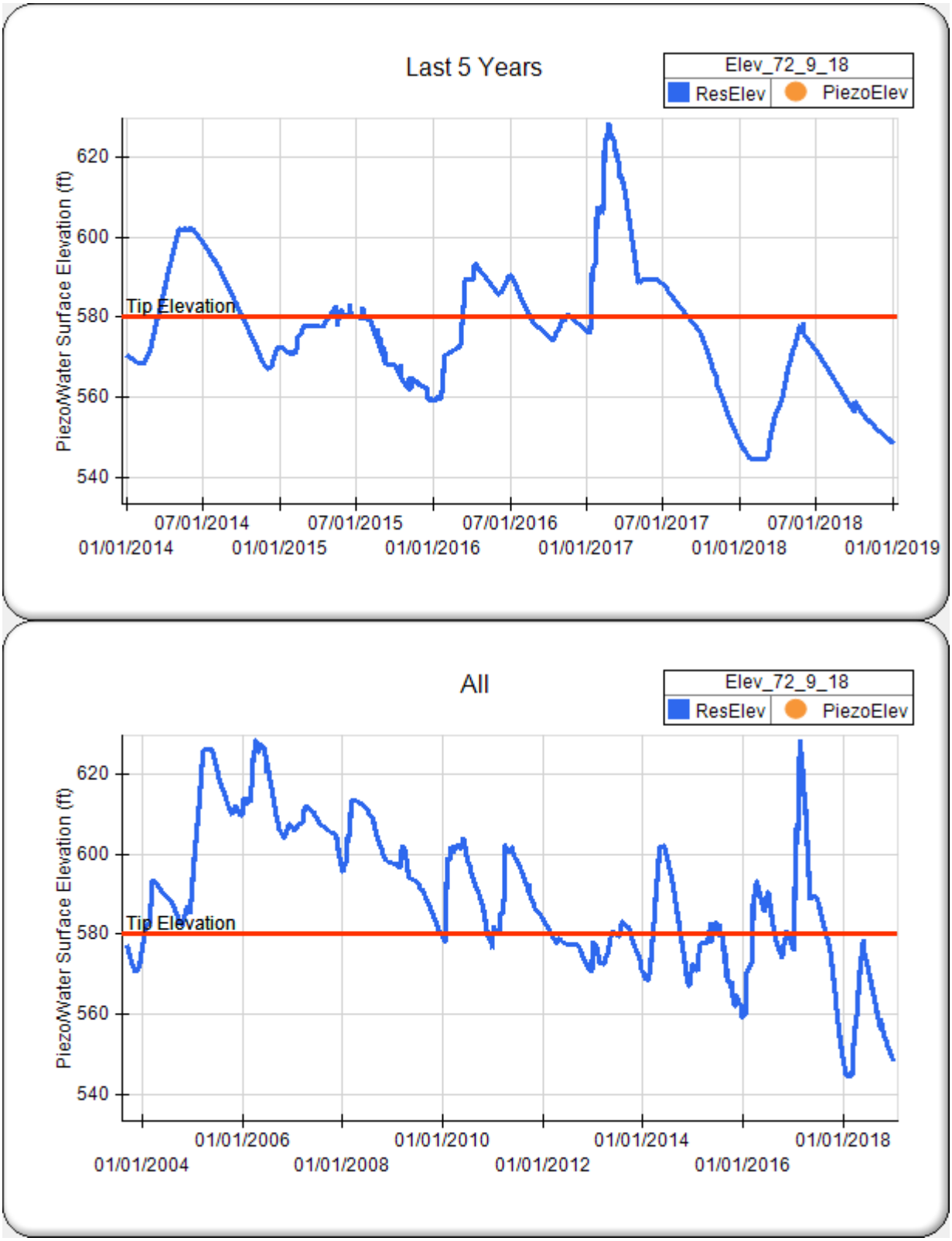


FIGURE 1-18

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

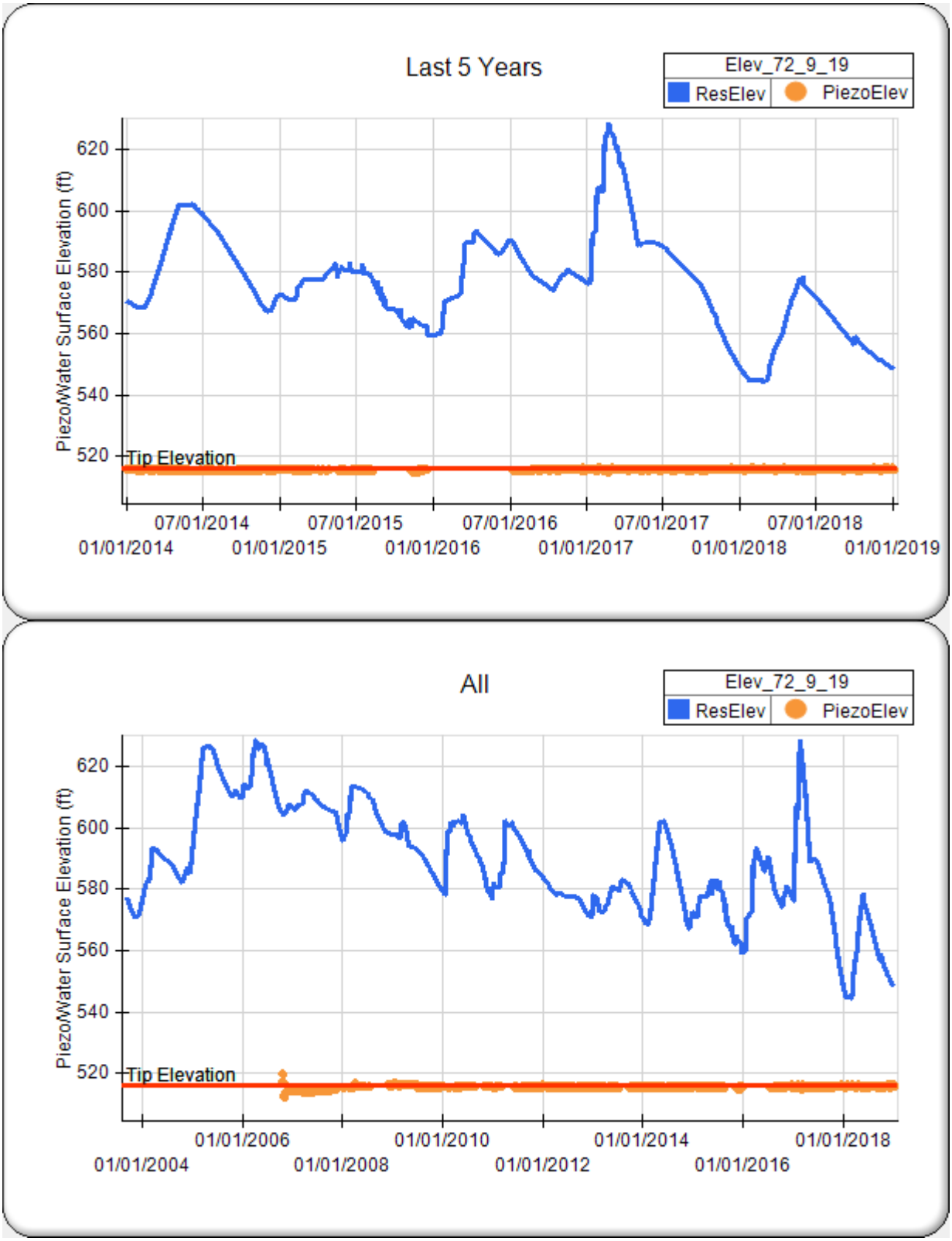
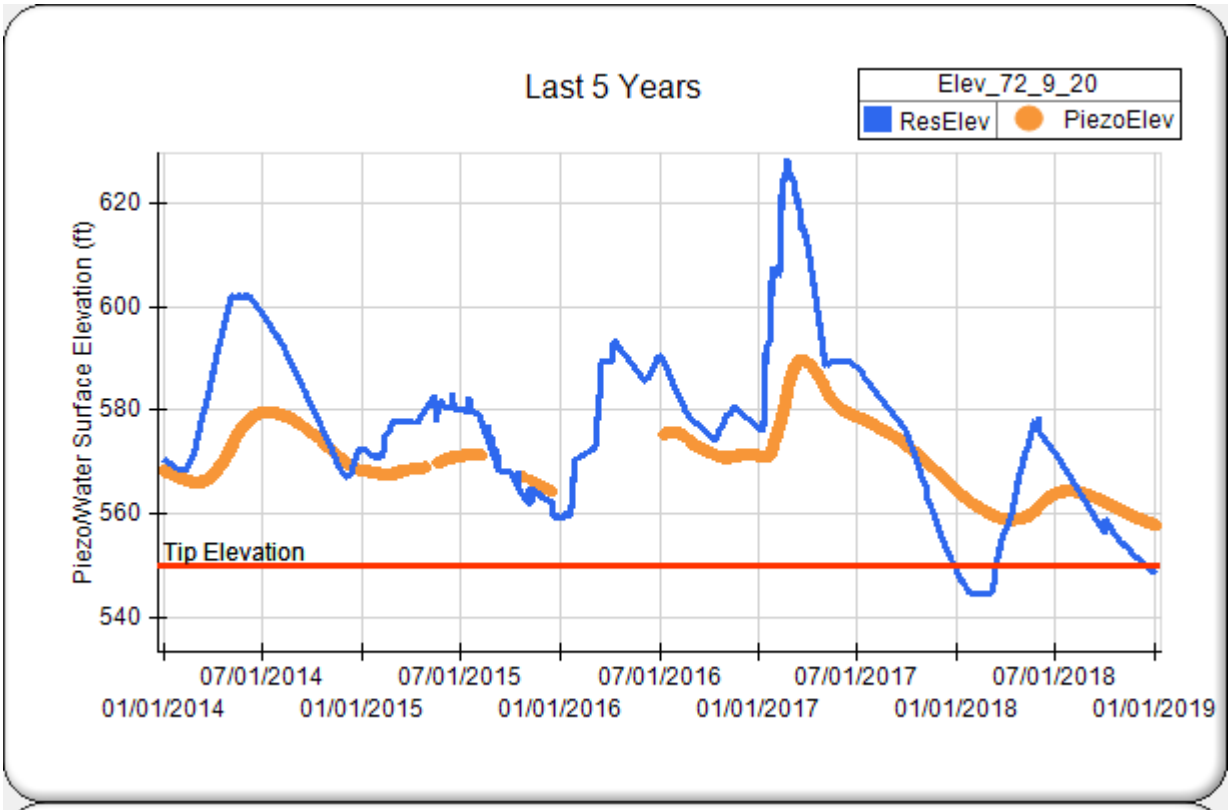


FIGURE 1-19

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots



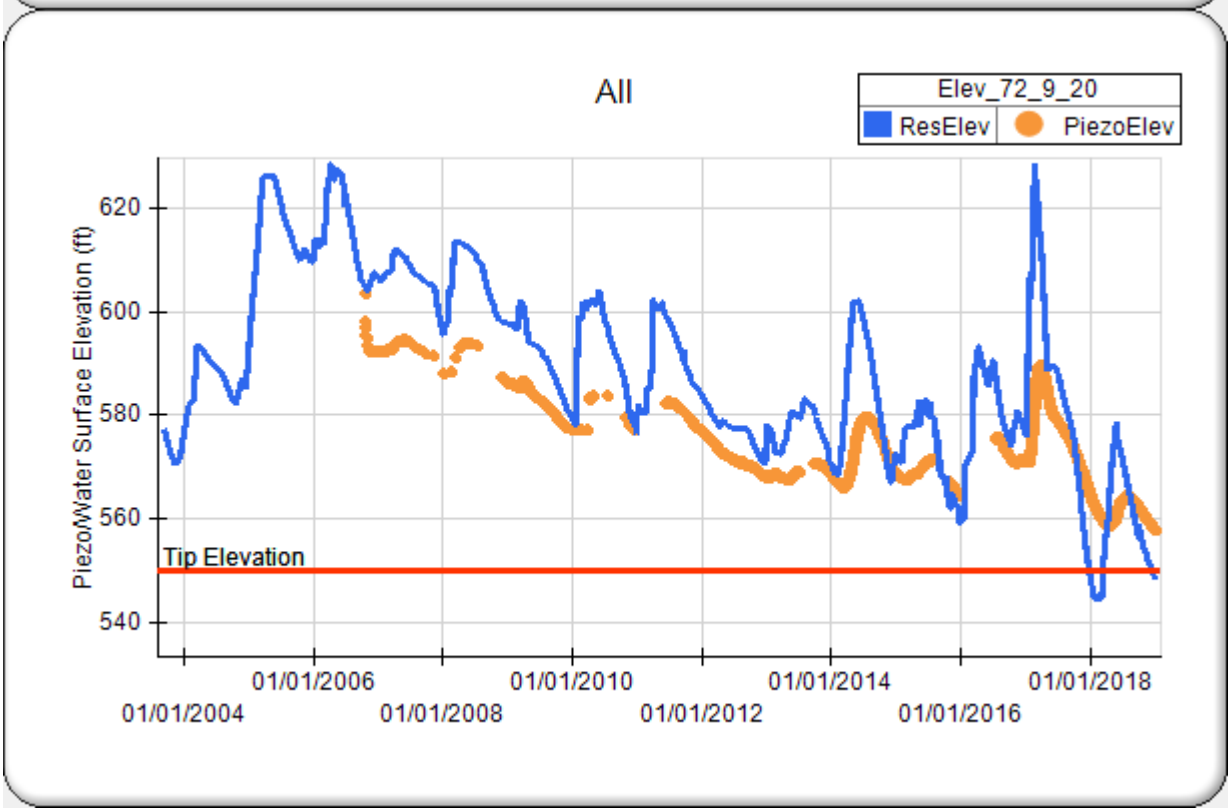
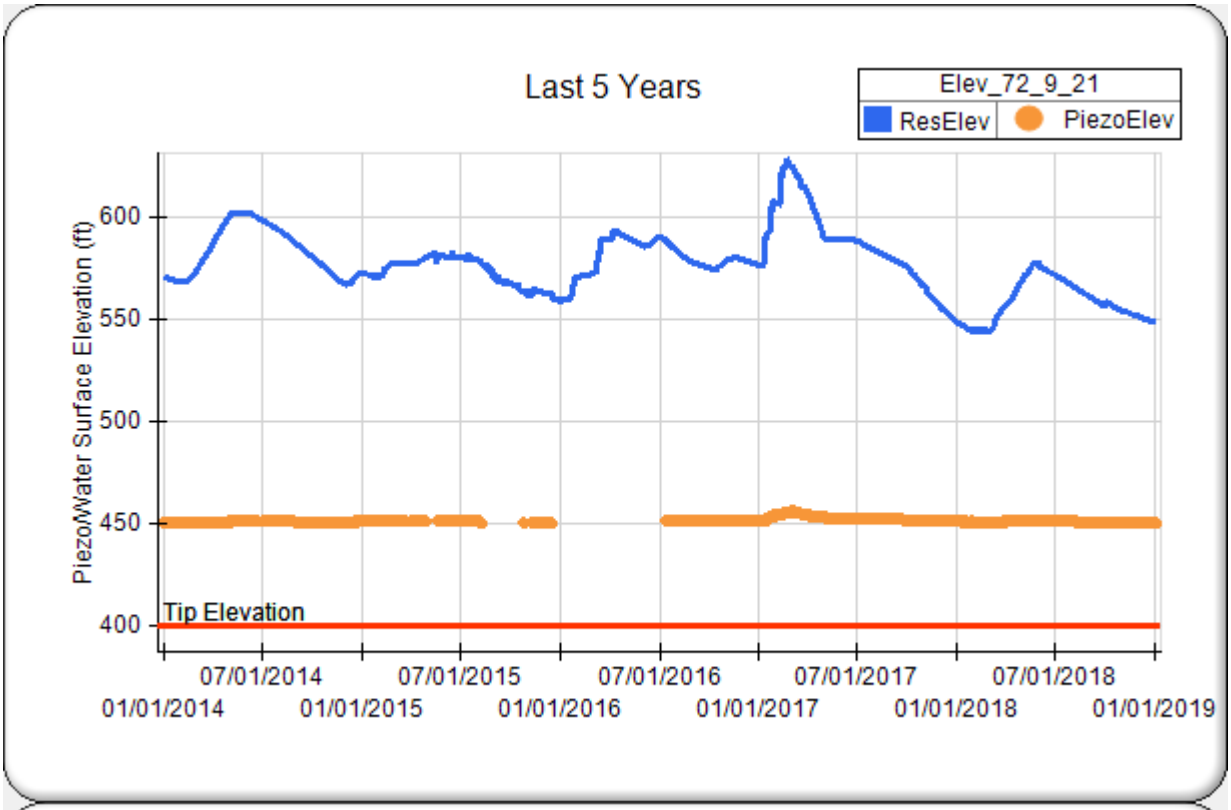


FIGURE 1-20

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots



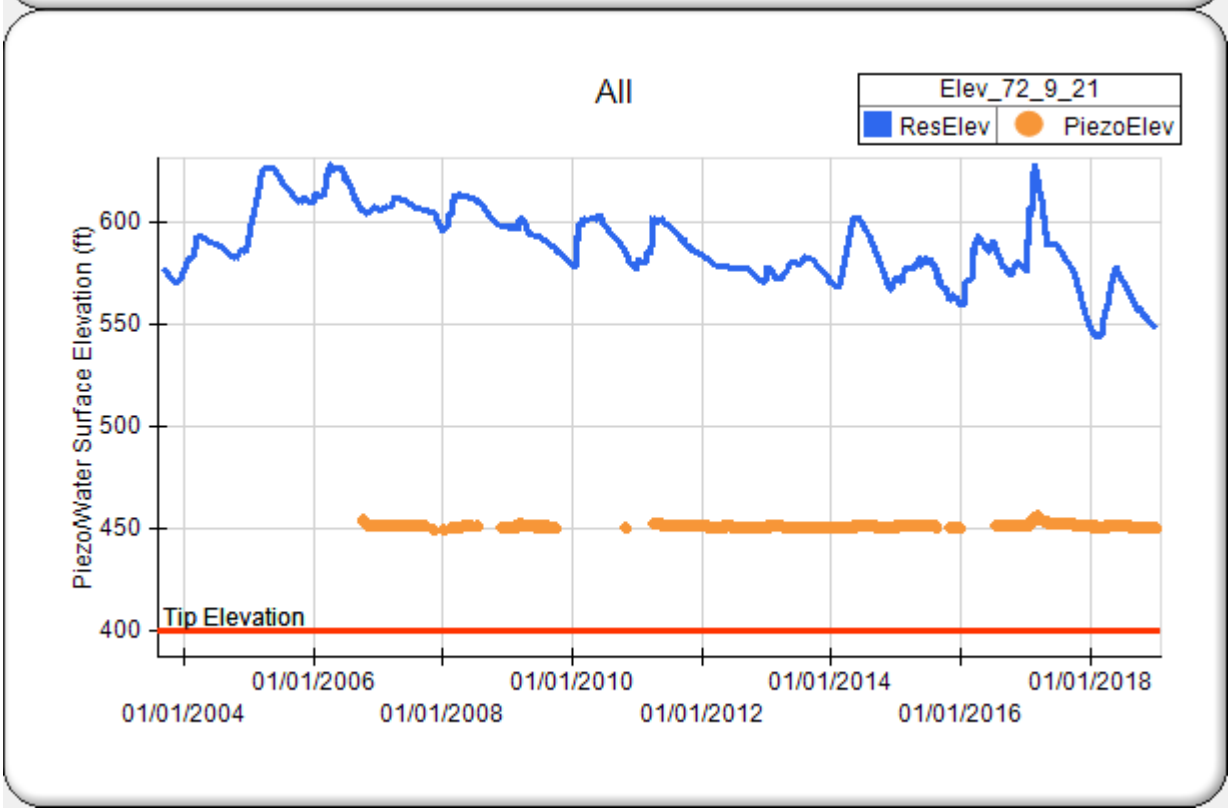


FIGURE 1-21

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

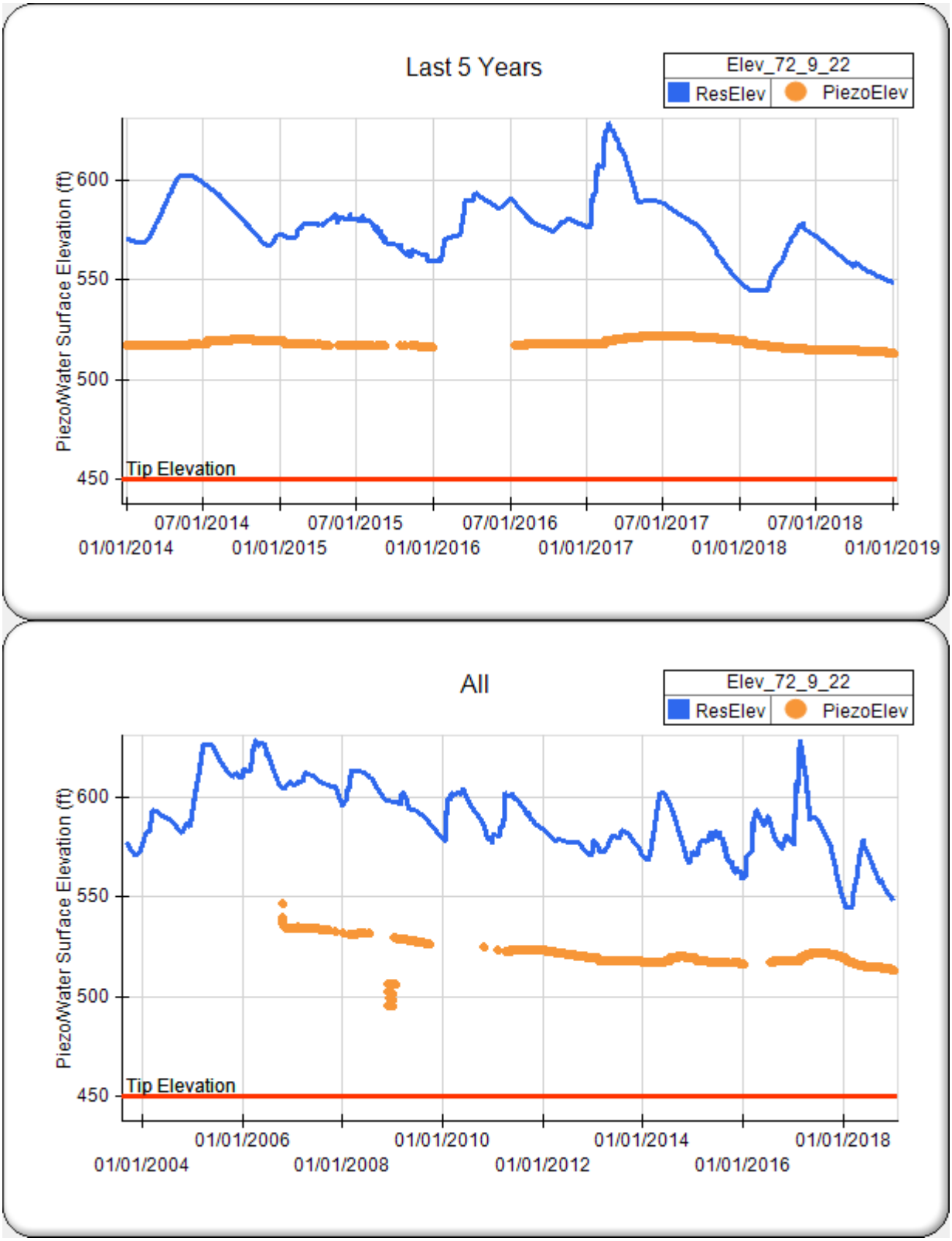
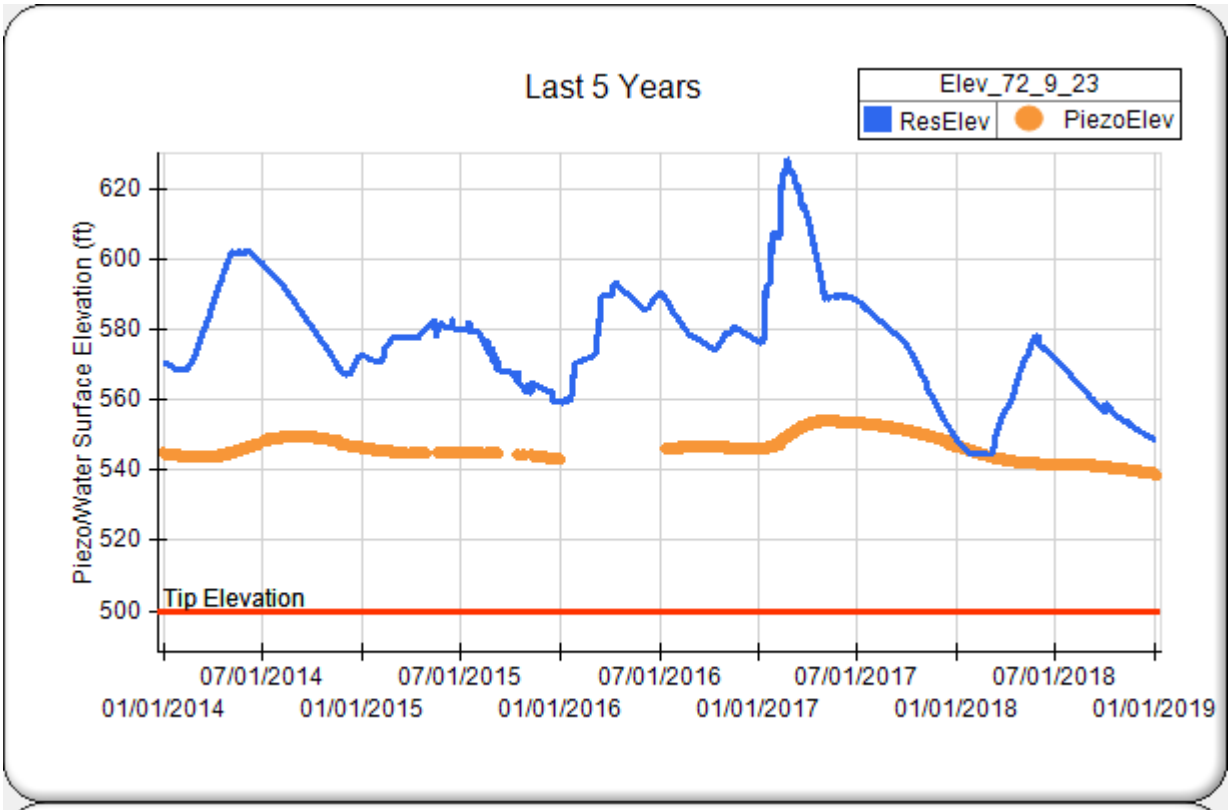


FIGURE 1-22

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots



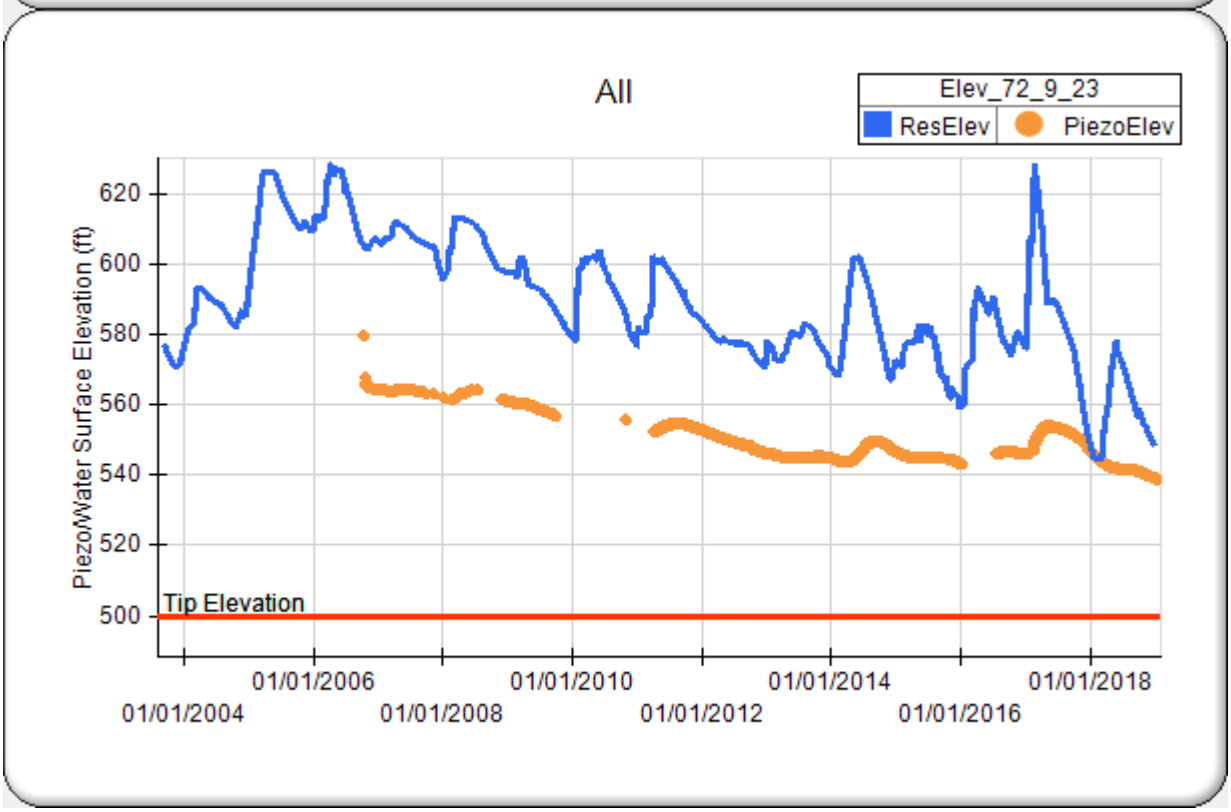
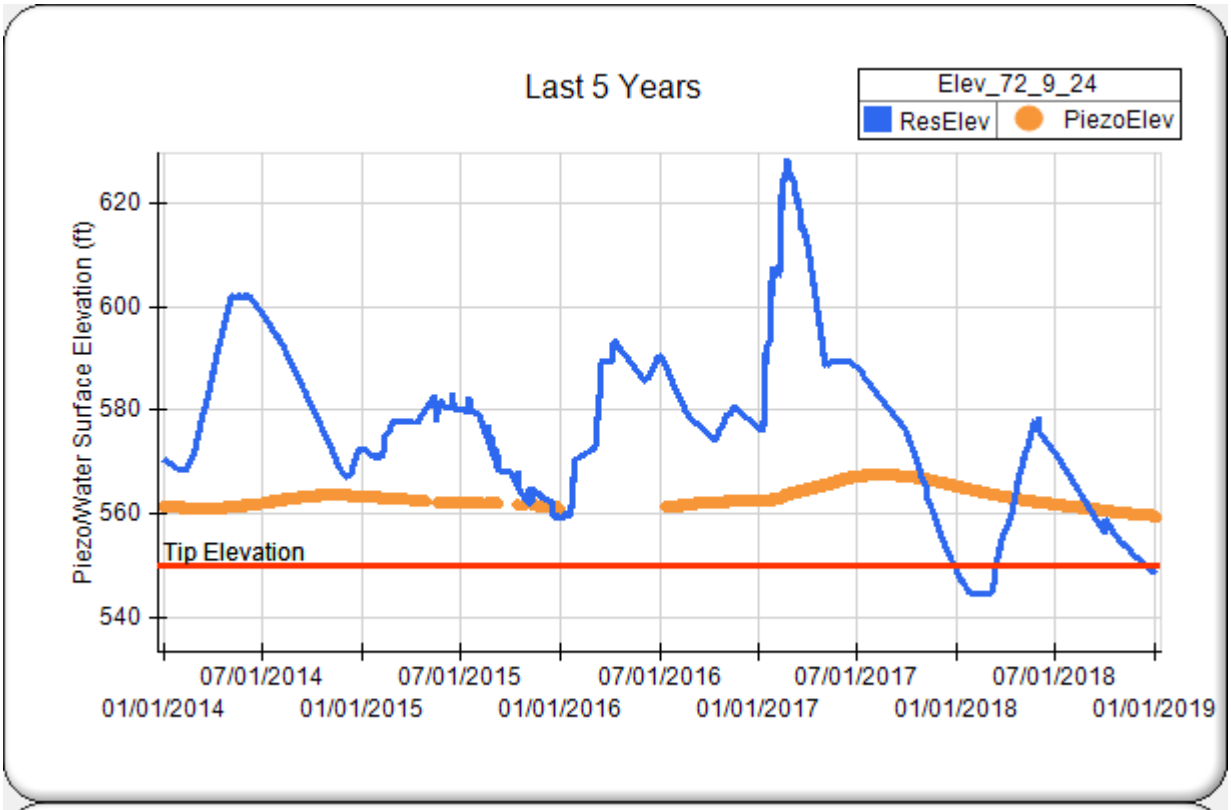


FIGURE 1-23

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots



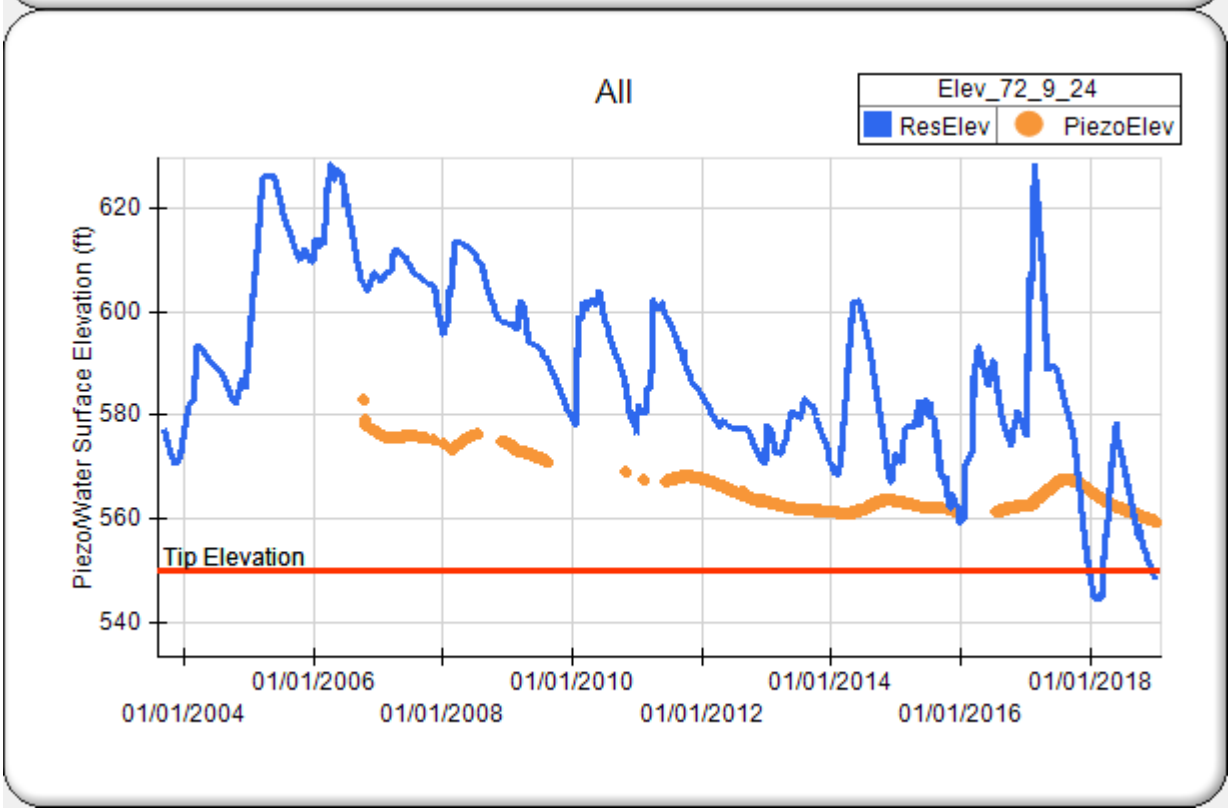


FIGURE 1-24

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

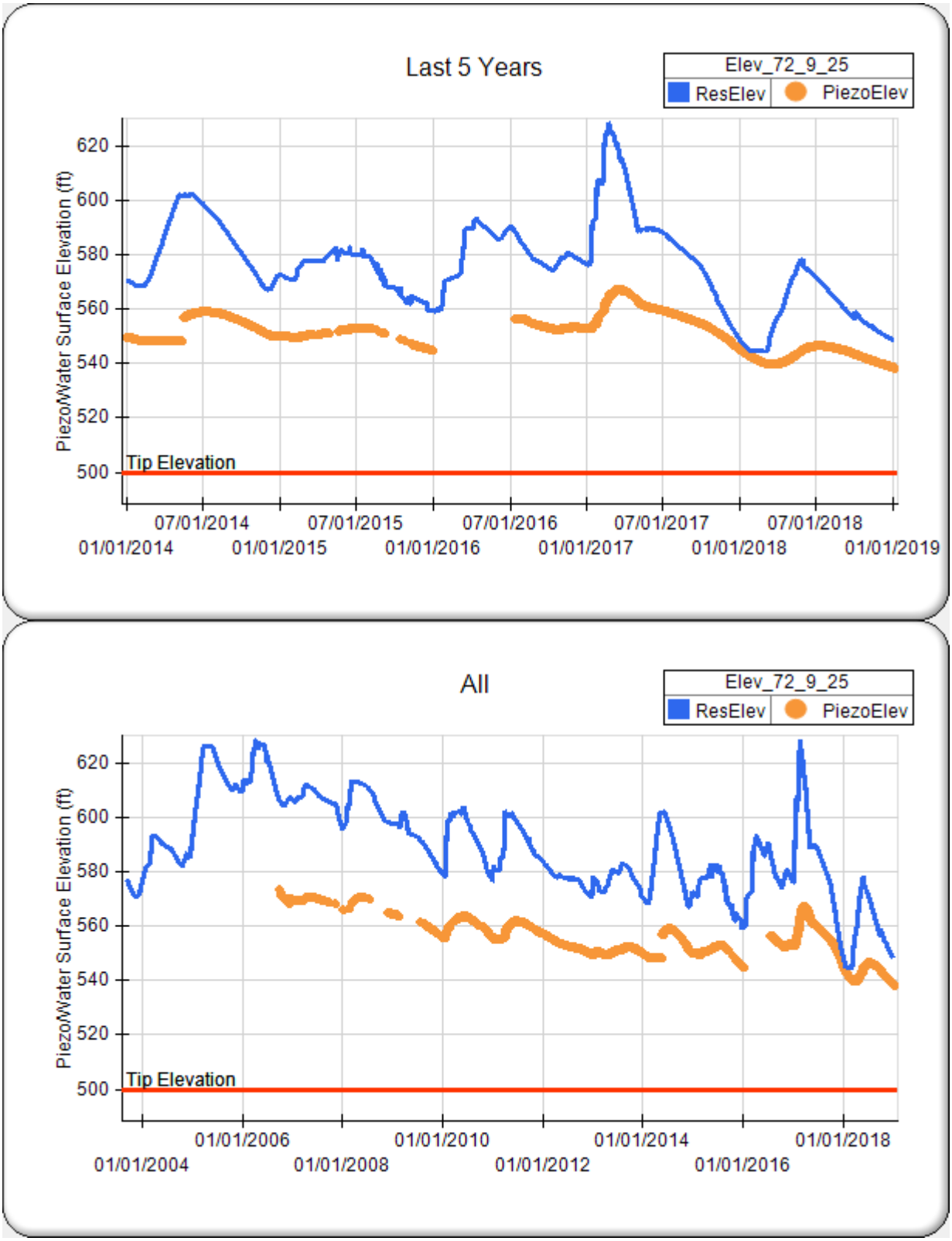
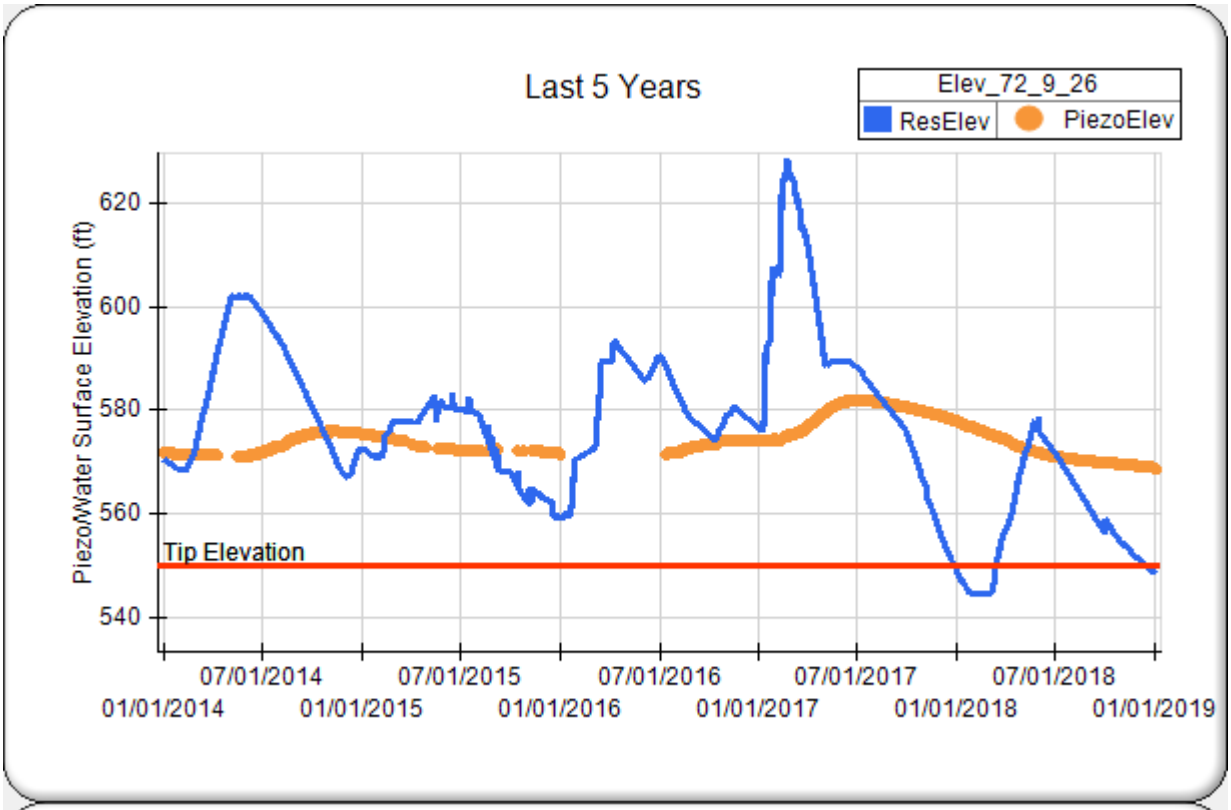


FIGURE 1-25

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots



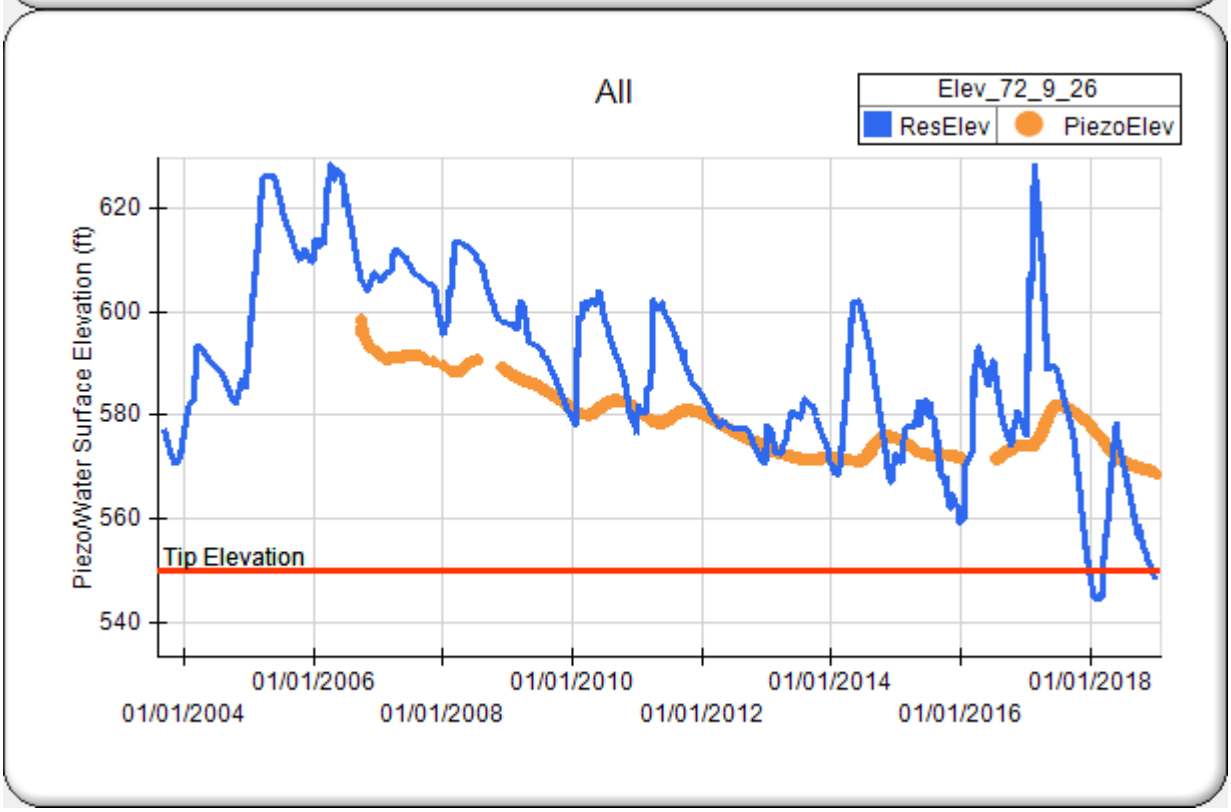


FIGURE 1-26

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

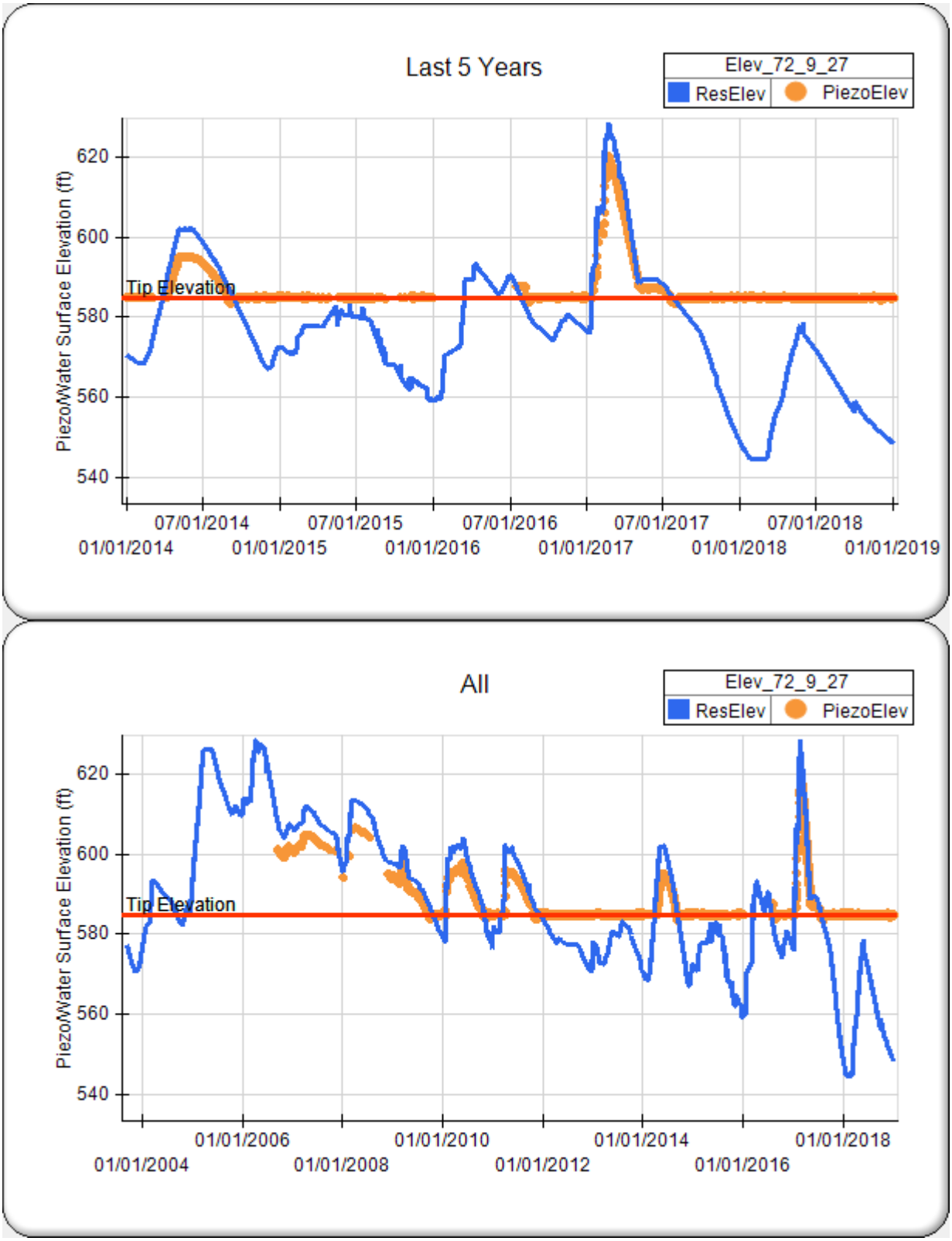
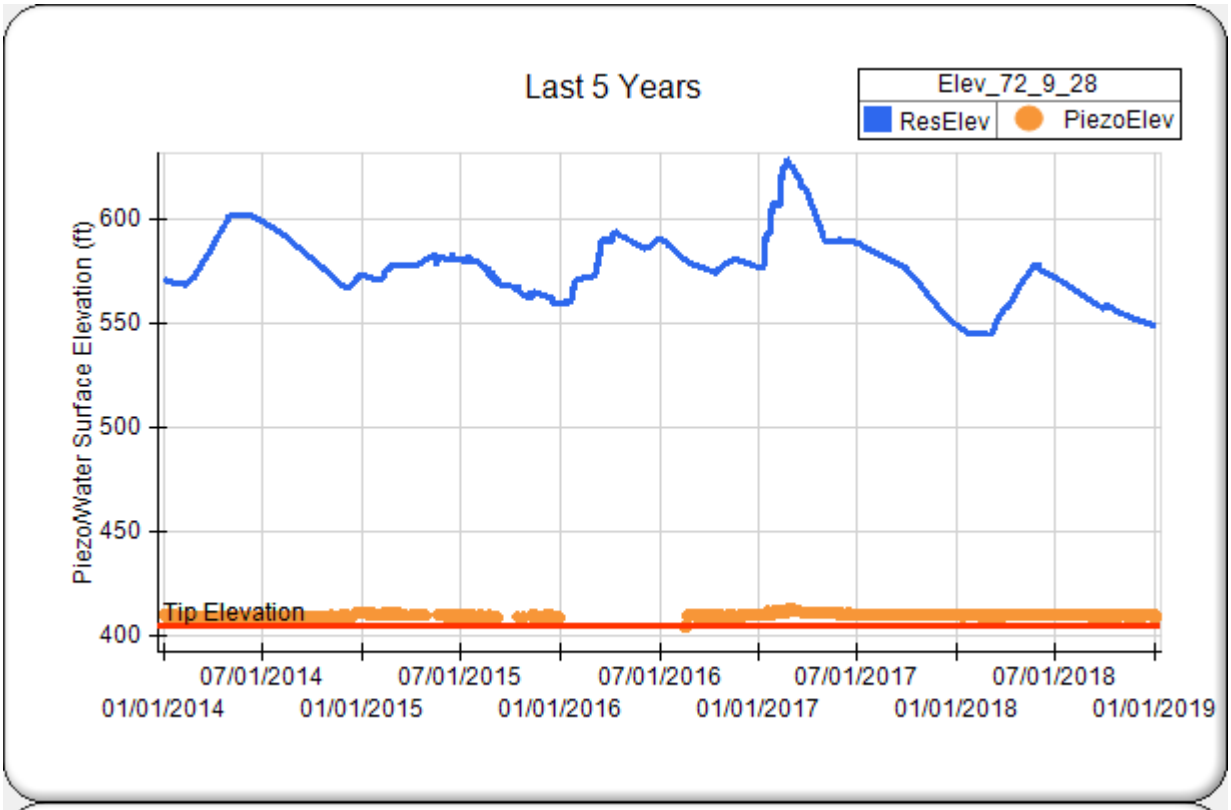


FIGURE 1-27

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots



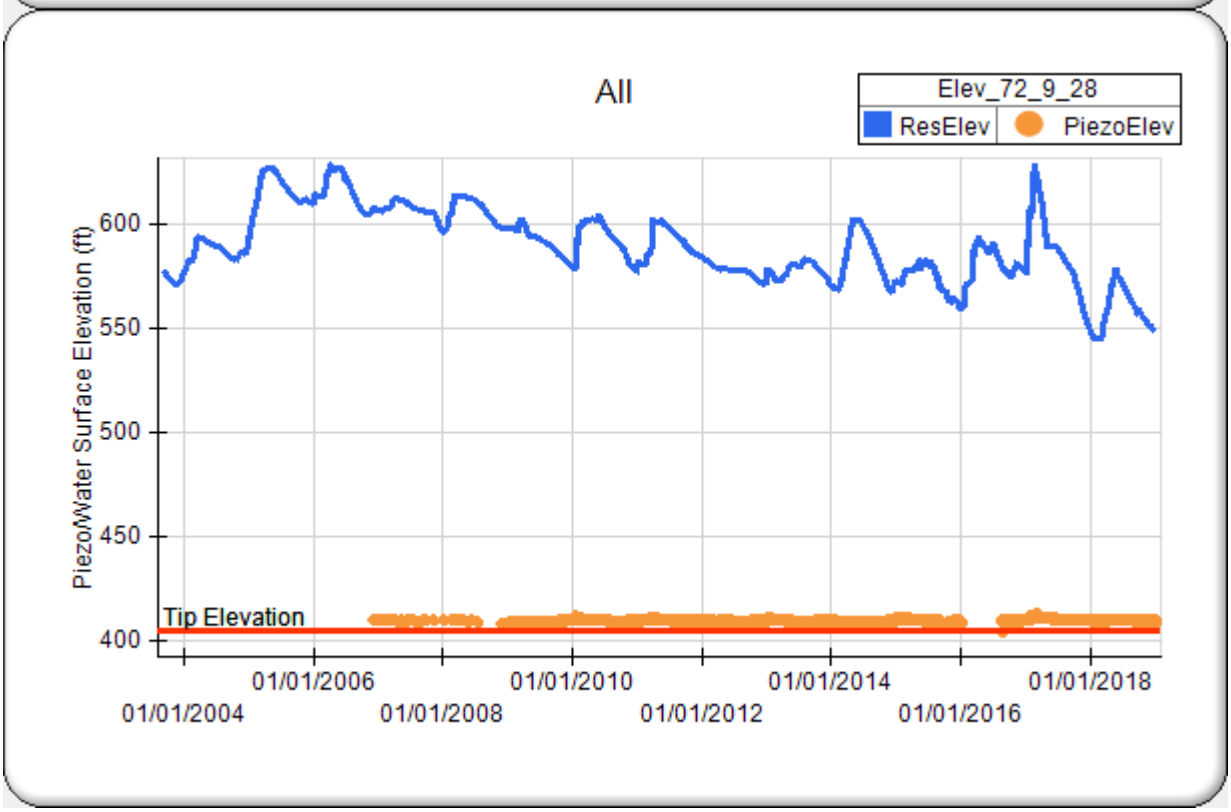


FIGURE 1-28

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

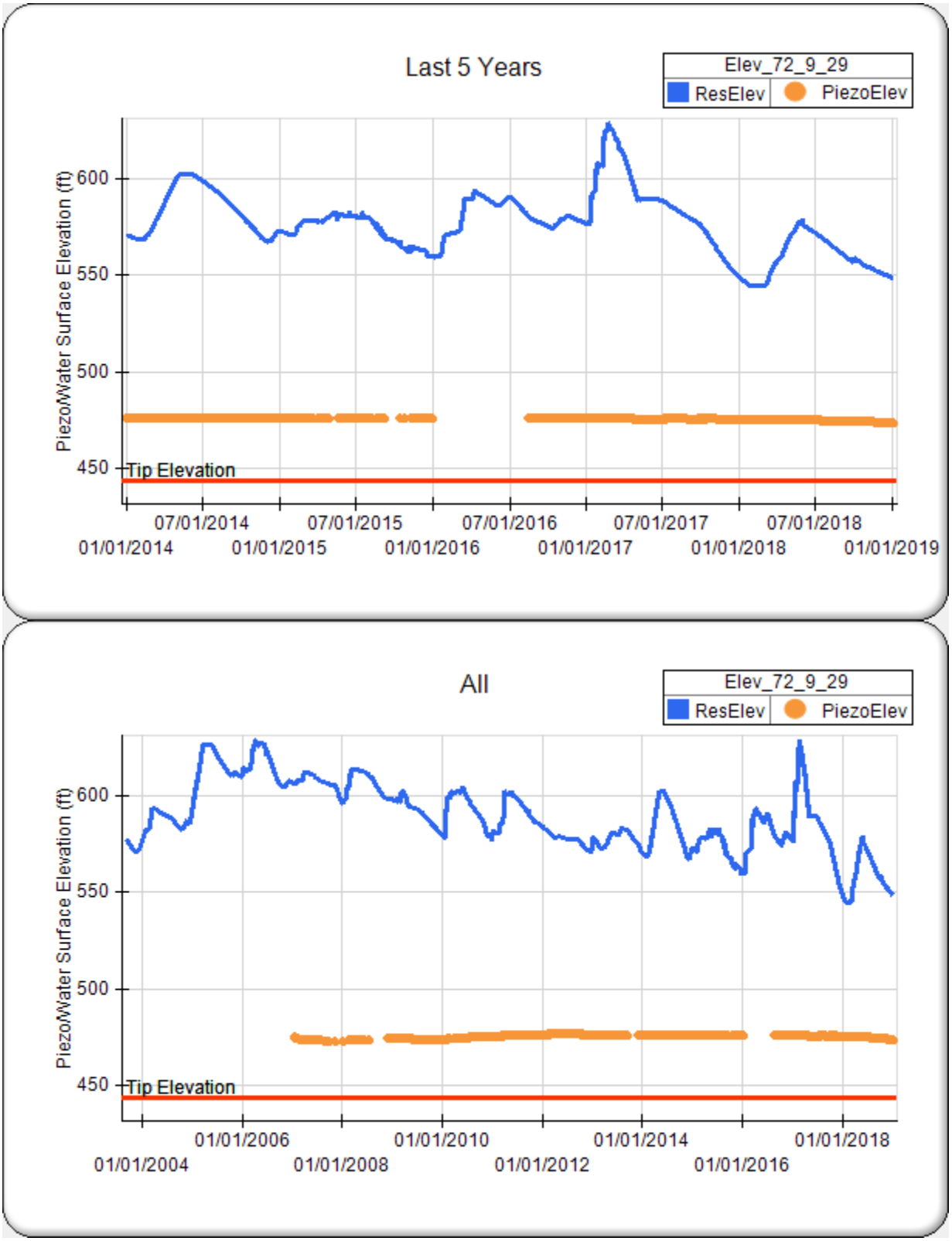


FIGURE 1-29

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

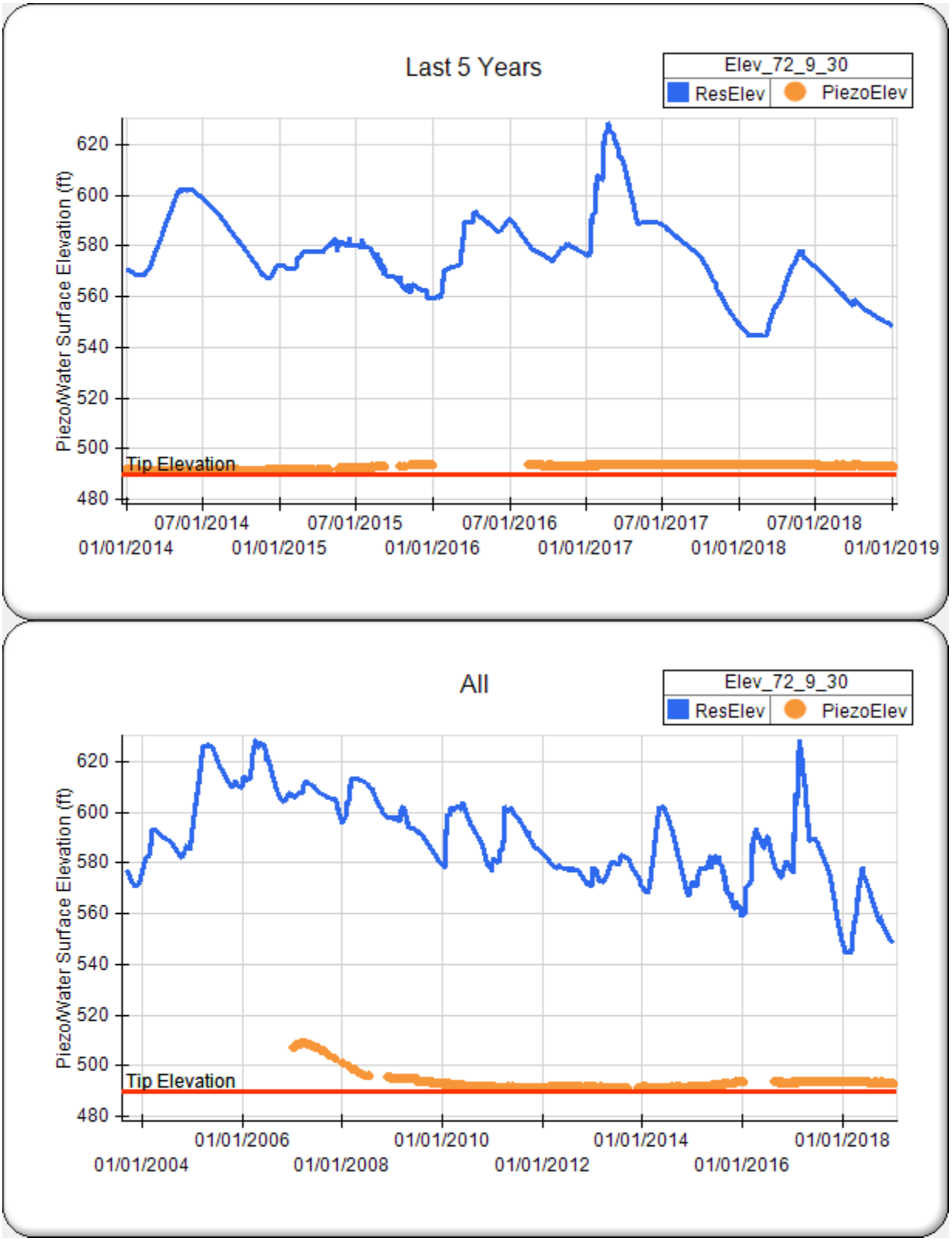


FIGURE 1-30

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

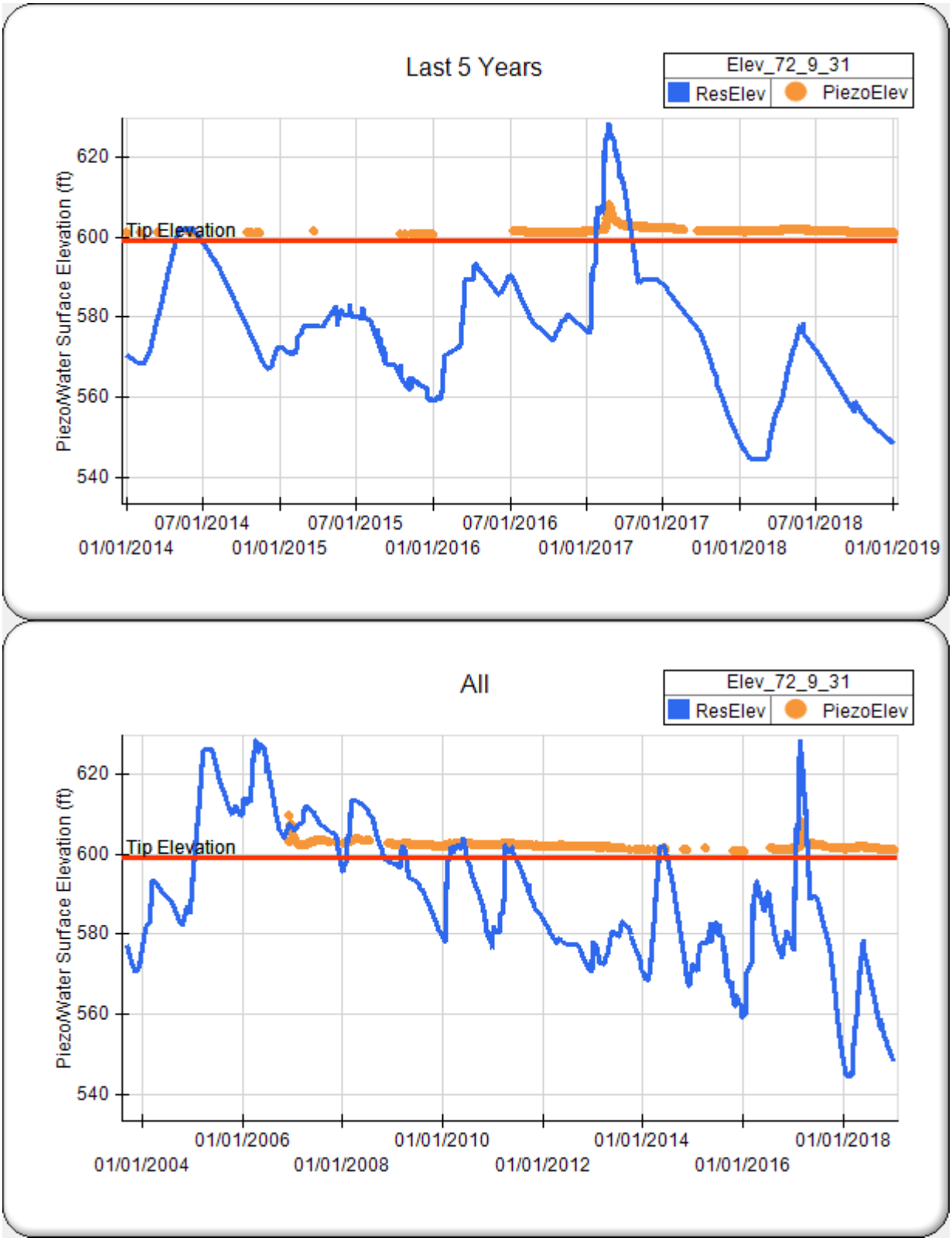


FIGURE 1-31

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

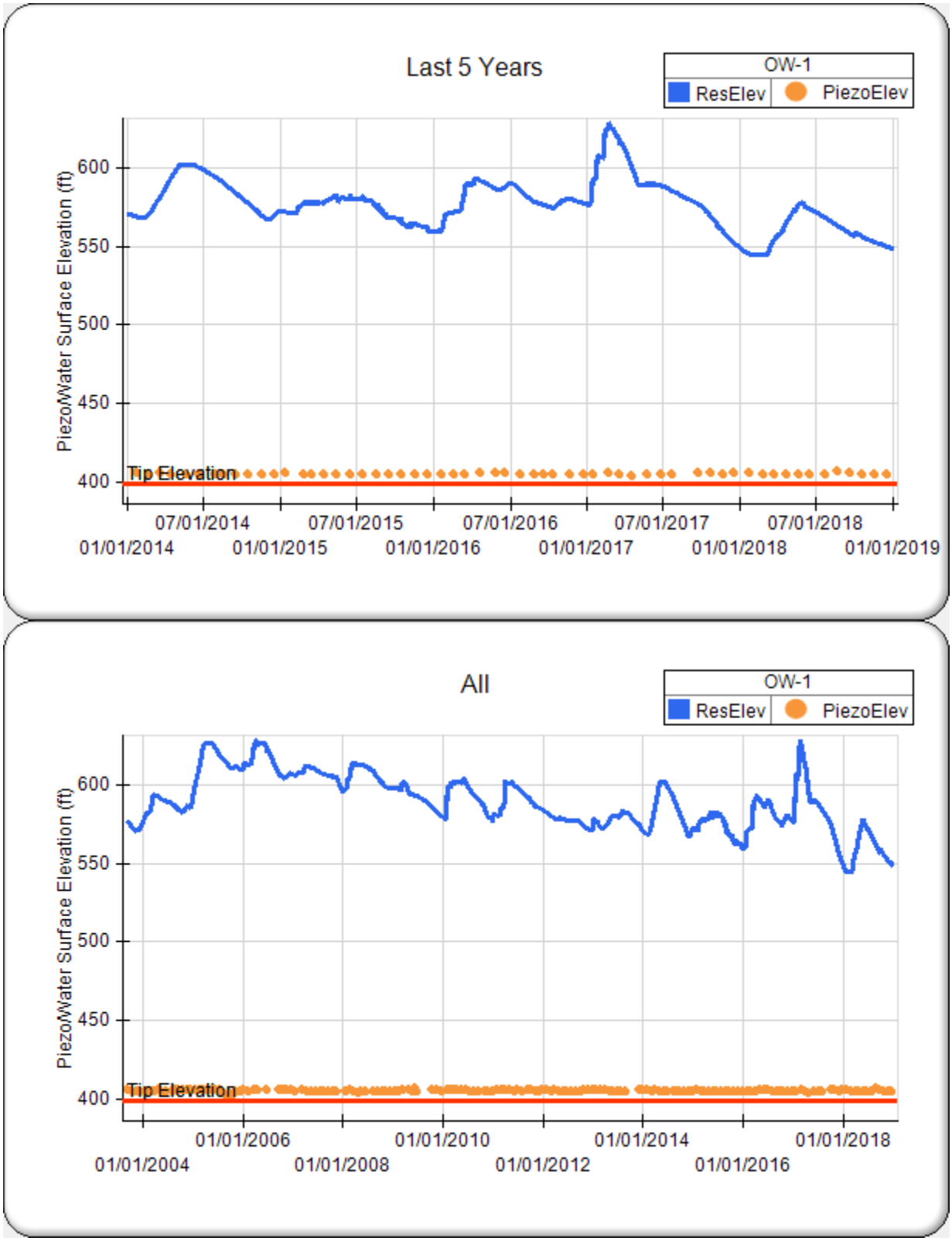


FIGURE 1-32

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots

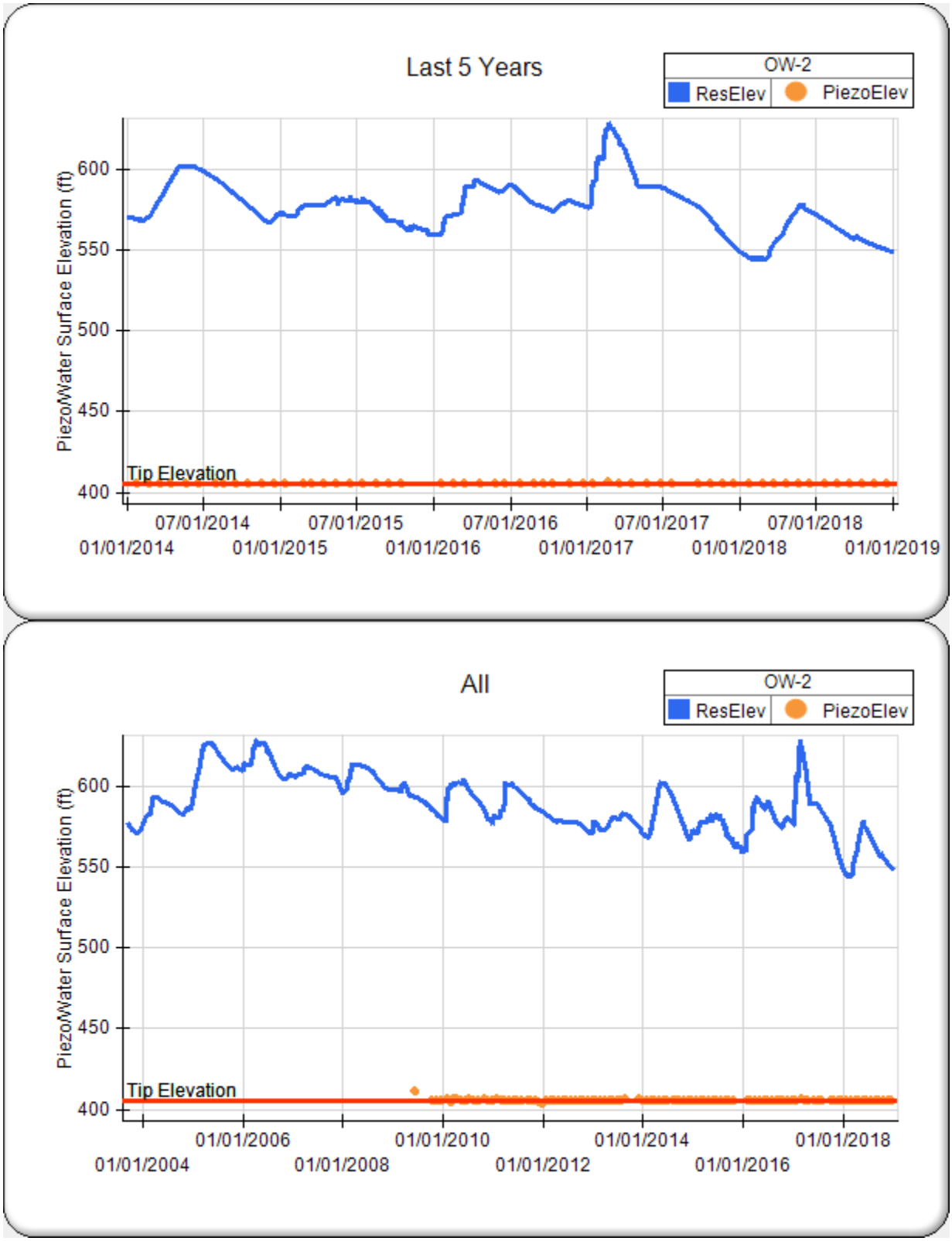
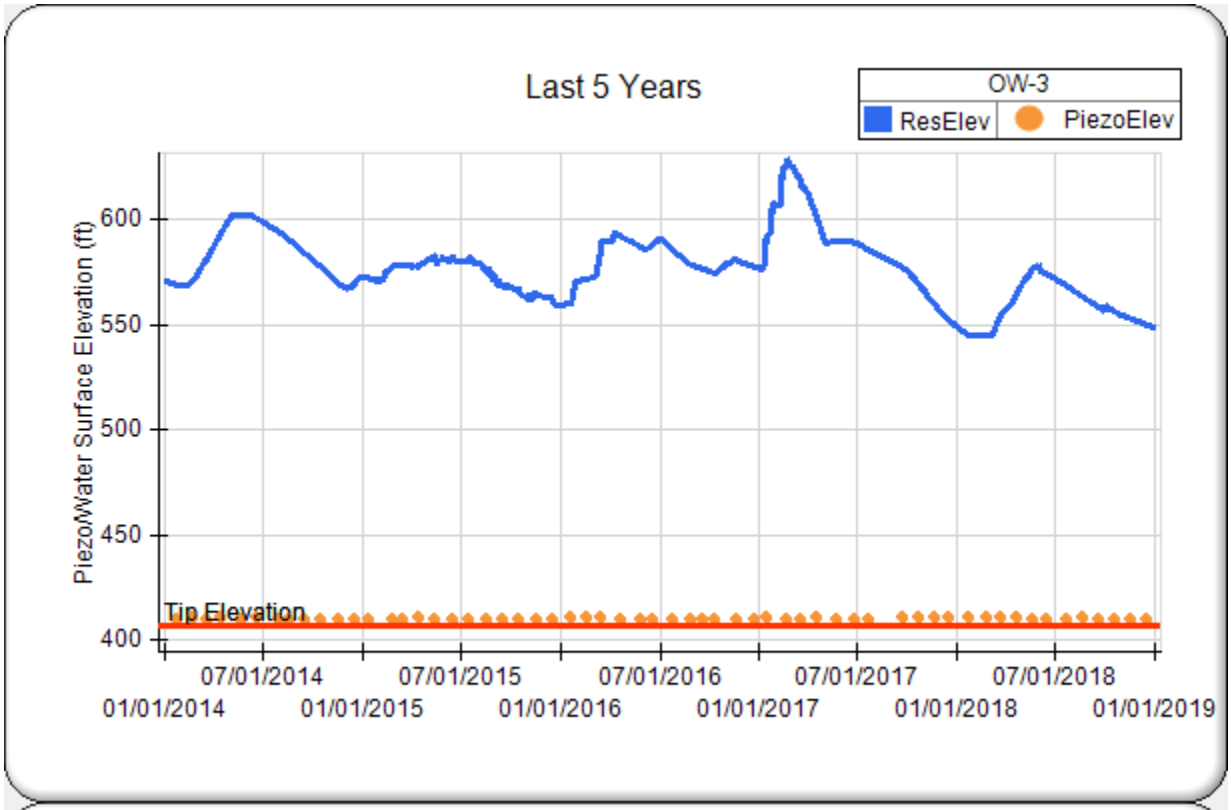


FIGURE 1-33

Anderson Dam Piezometers and Reservoir Elevation - Time Series Plots



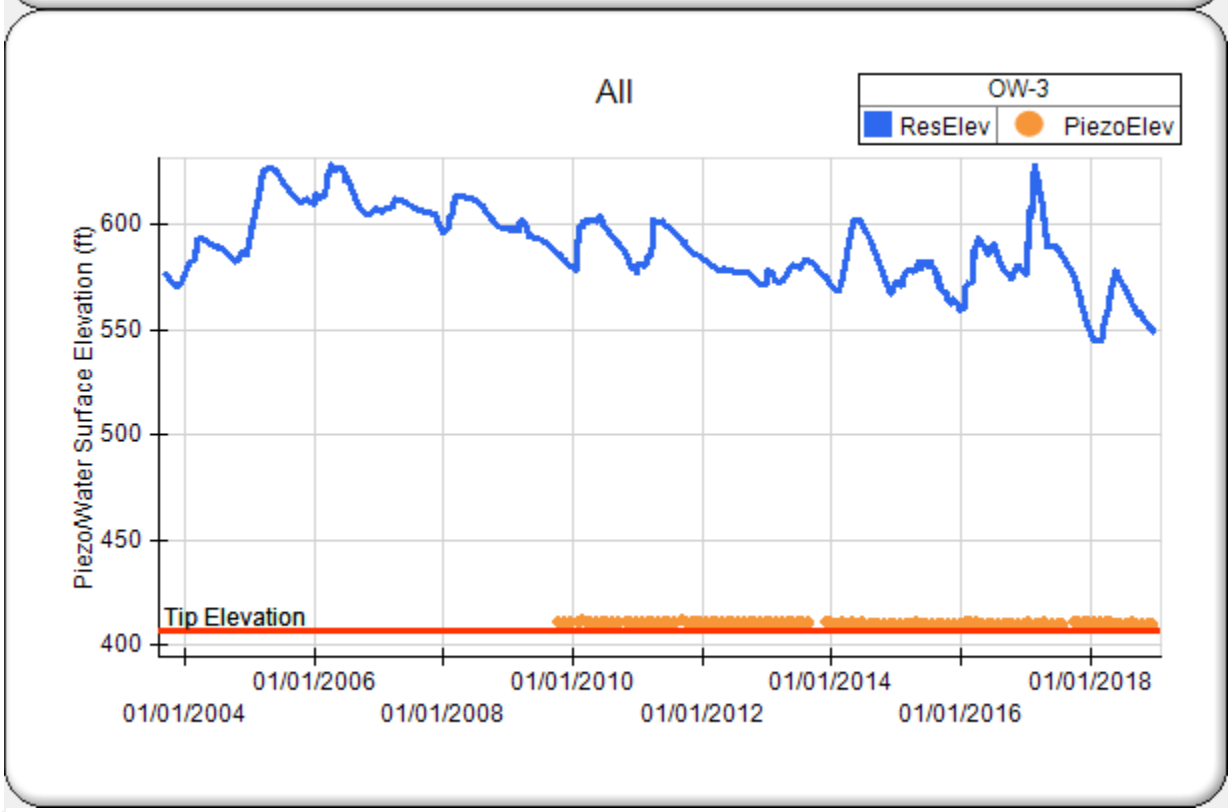
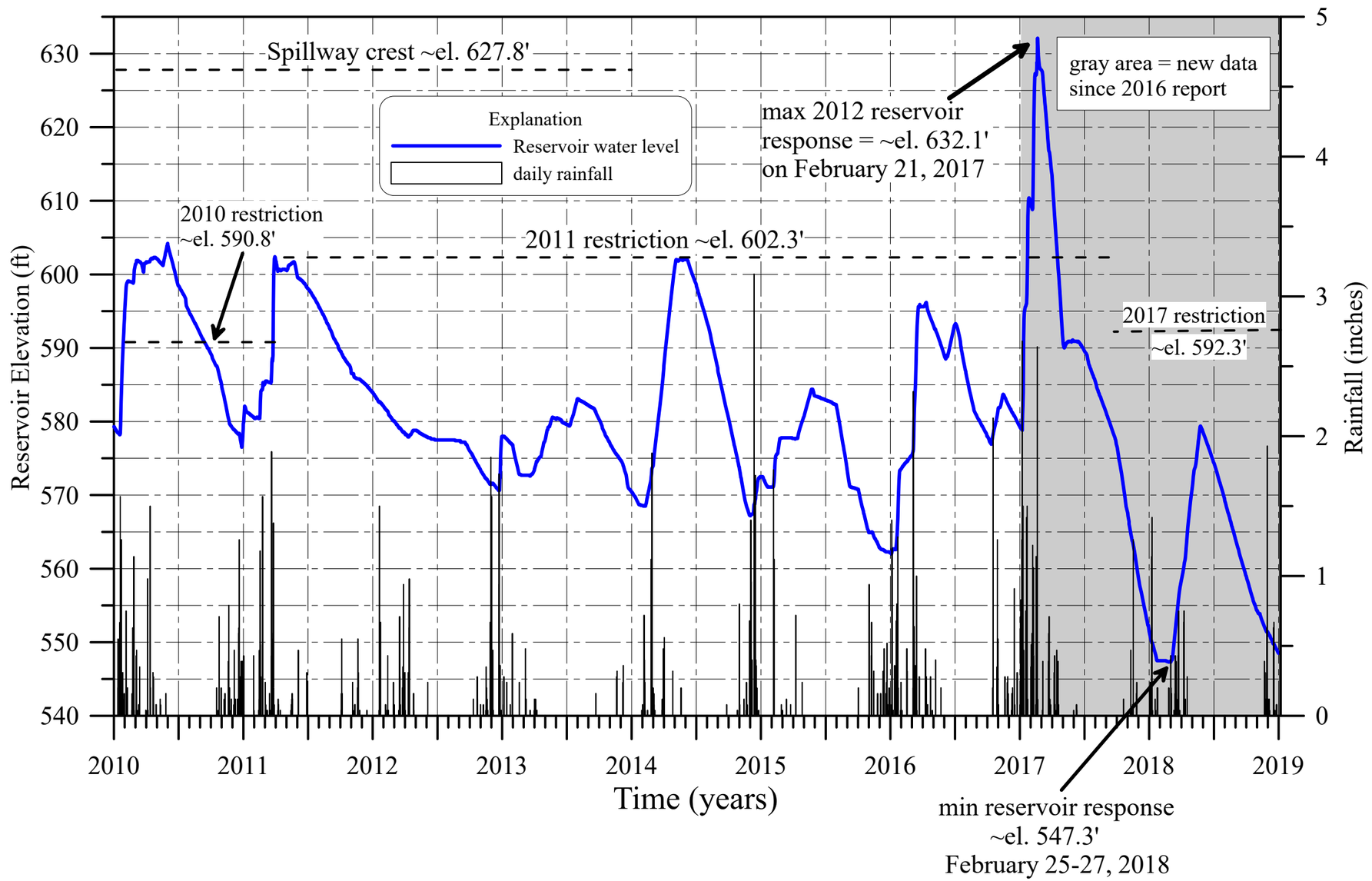


FIGURE 1-34

Daily Reservoir Elevation and Rainfall 2010-2018

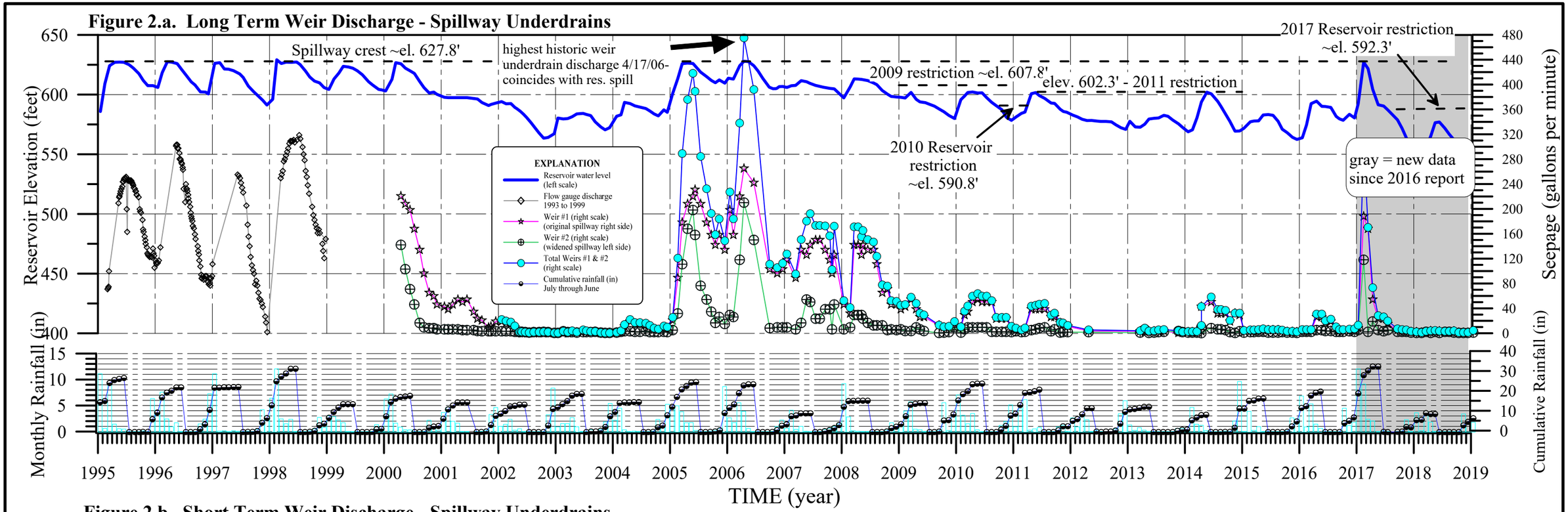


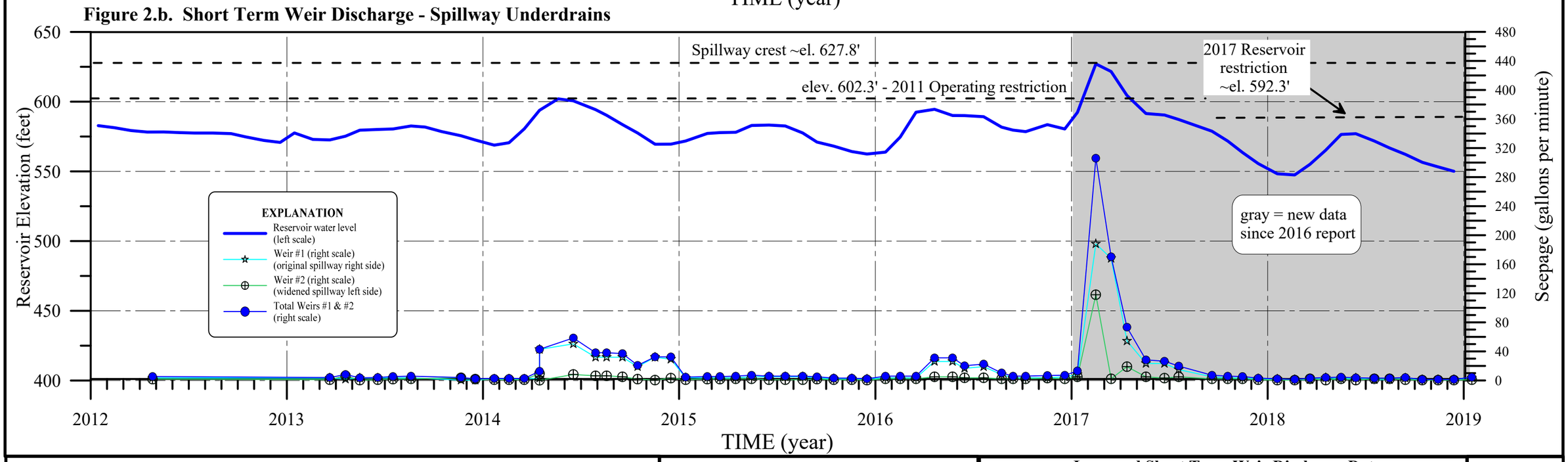
Notes: 1) basis of elevations is NAVD 1988 - values are 2.8 feet higher than NGVD 1929
2) file W:\geology\dams\annual dam safety reports\DSOD\Anderson\2018\piez\Andresplot-18

Santa Clara Valley Water District

Daily Reservoir Elevation and Rainfall 2010-2018
Leroy Anderson Dam

FIGURE 2



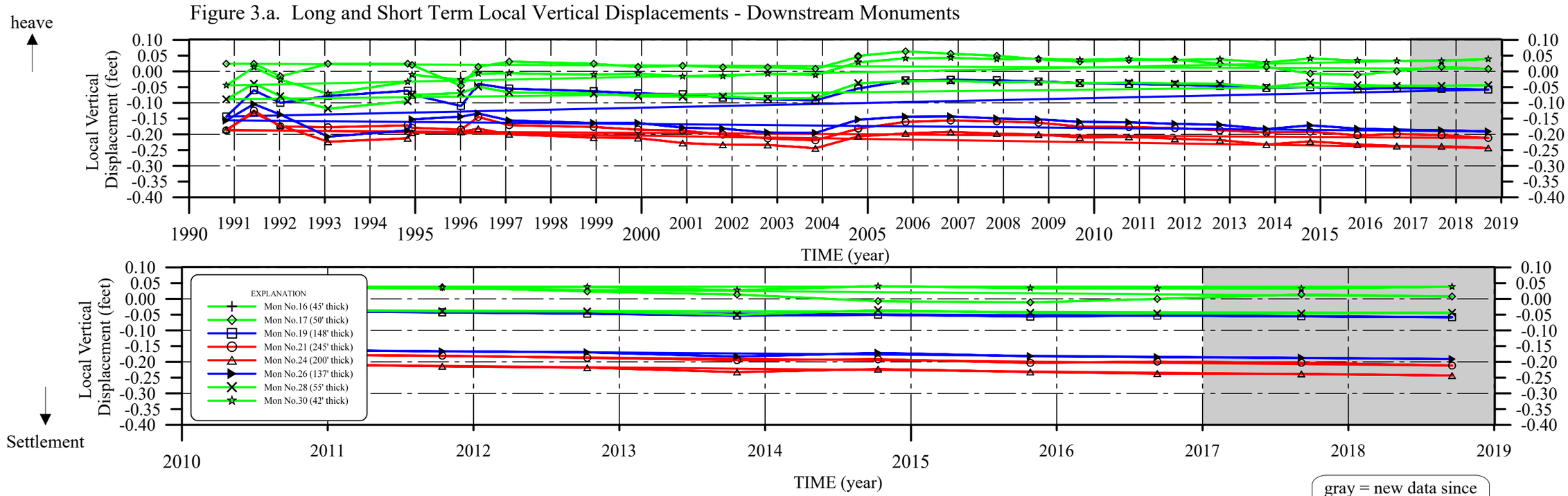


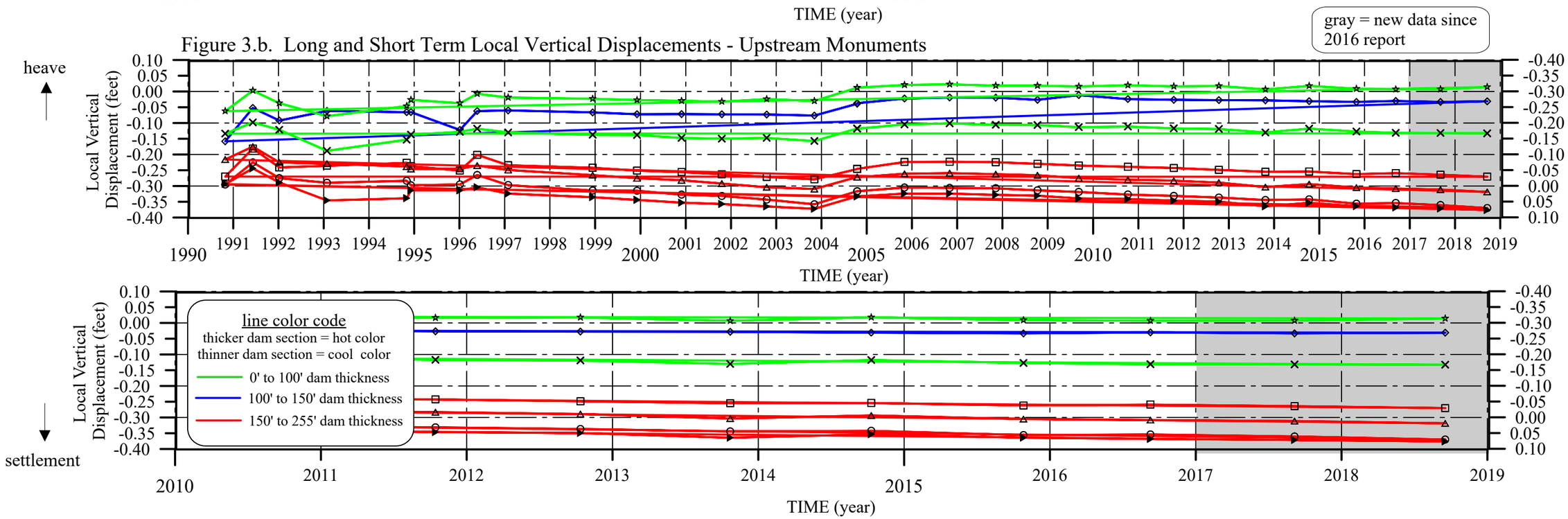
Notes:
1) Basis of elevations is NAVD 1988 - values on this plot are 2.8 feet higher than NGVD 1928
2) File W:\Geology\DAMS\Annual Dam Safety Reports\2018\Weir\Andweir-18.grf

Santa Clara Valley Water District

Long and Short Term Weir Discharge Data
Spillway Underdrains
Leroy Anderson Dam

FIGURE
3





Notes:
1) File W:\Geology\DAMS\Annual Dam Safety Reports\2018\Survey\AndDSODDS&USvertPlots-18.grf
2) Since the 2004 survey the District no longer shows changes in datums

Santa Clara Valley Water District

Long and Short Term Local Vertical Displacement - Downstream and Upstream Crest Monuments
Leroy Anderson Dam

FIGURE 4

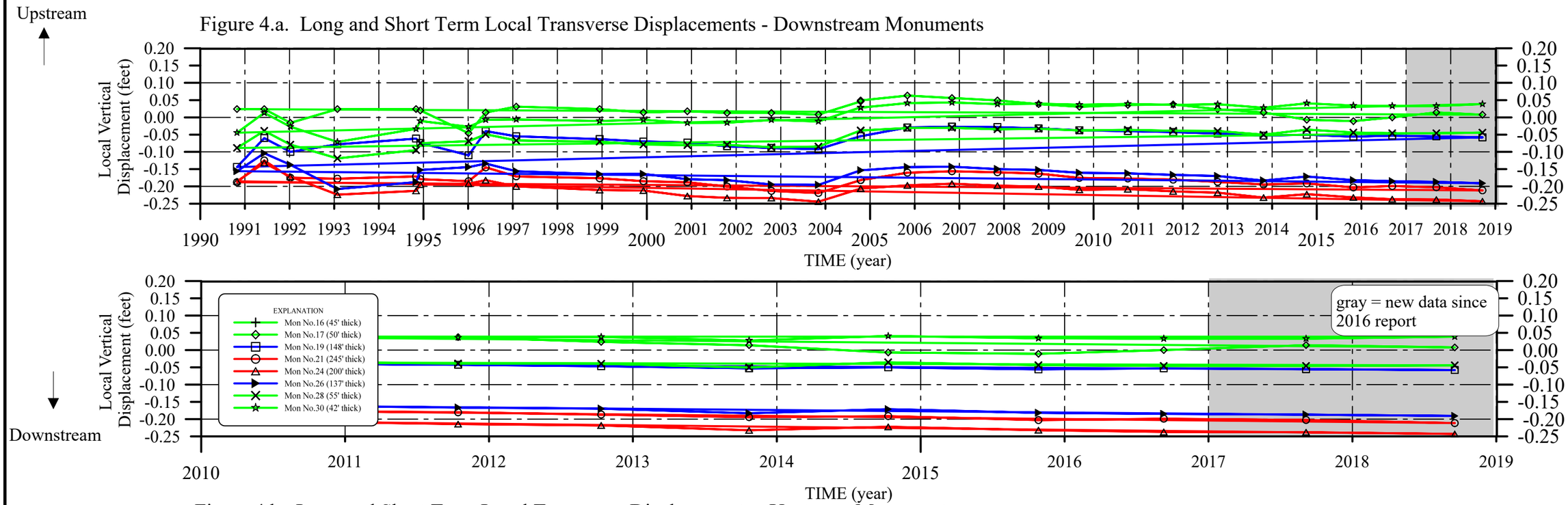


Figure 4.a. Long and Short Term Local Transverse Displacements - Downstream Monuments

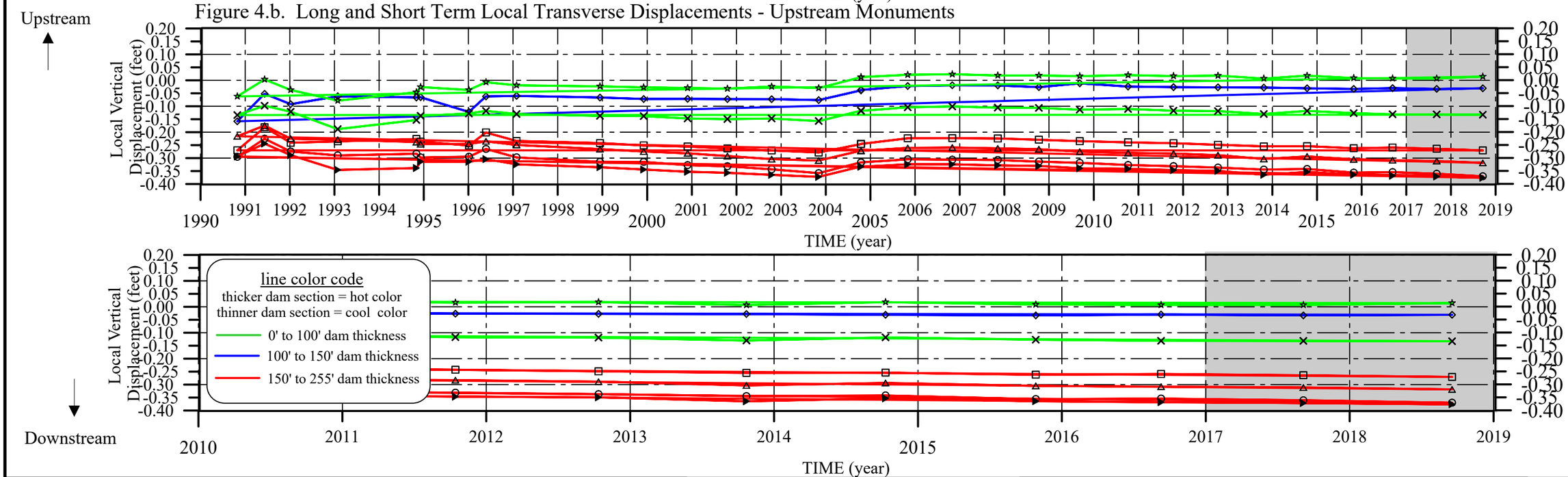


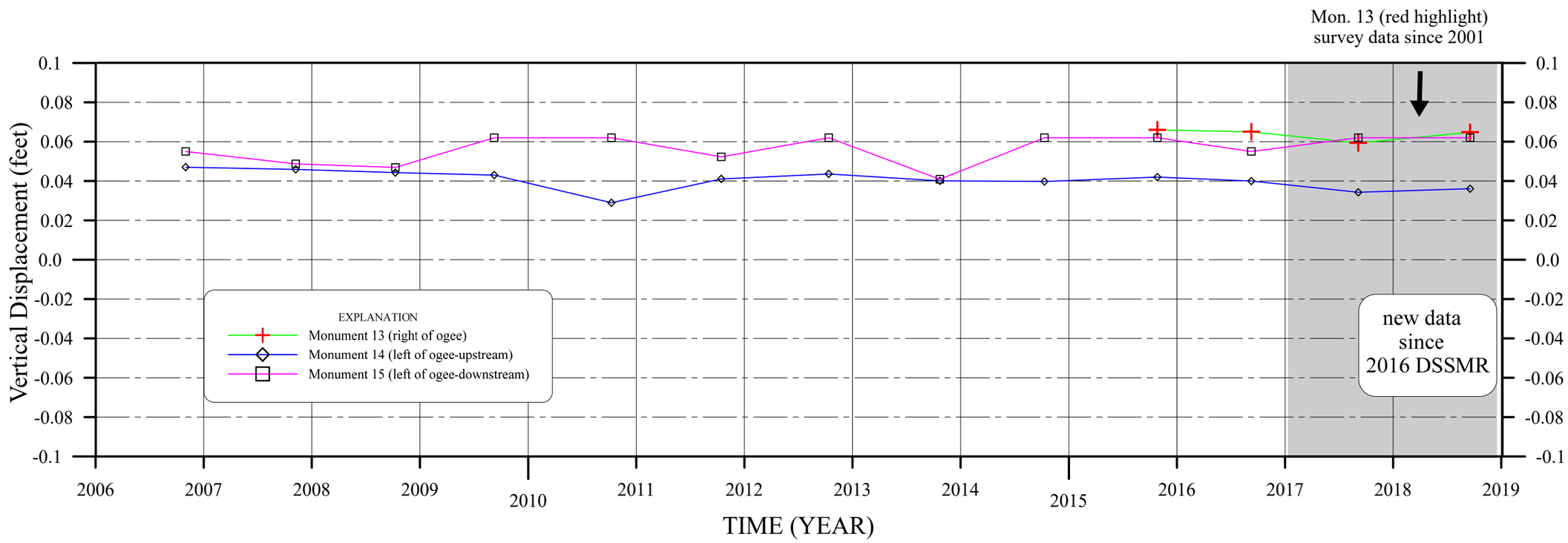
Figure 4.b. Long and Short Term Local Transverse Displacements - Upstream Monuments

Notes:
1) File W:\Geology\DAMS\Annual Dam Safety Reports\2018\Survey\AndDS&UTransPlots-18.grf
2) Since the 2004 survey the District no longer shows changes in datums

Santa Clara Valley Water District

Long and Short Term Local Transverse Displacement - Downstream and Upstream Crest Monuments
Leroy Anderson Dam

FIGURE 5



Notes:
1) Mon. 13 not surveyed since October 2001
2) File W:\Geology\DAMS\Annual Dam Safety Reports\2018\Survey\AndTrainWVert-18.grf
3) Since the 2004 survey the District no longer shows changes in datums

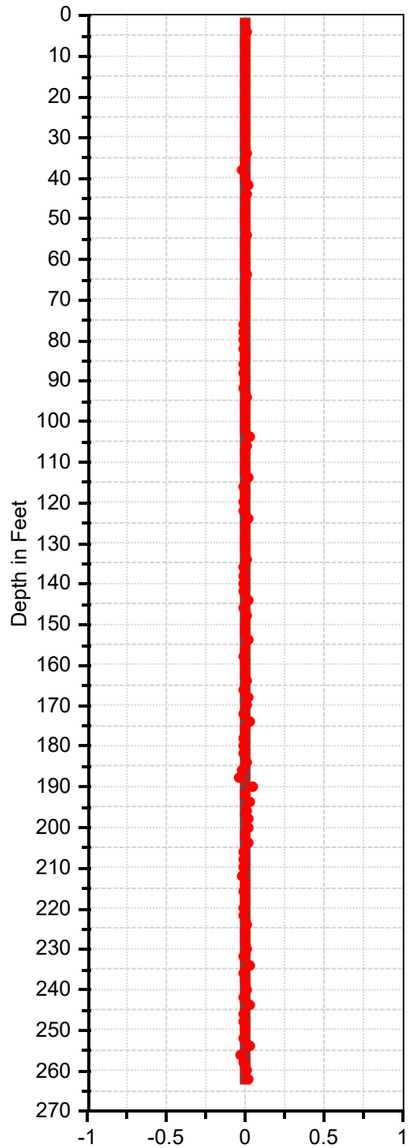
Santa Clara Valley Water District

Vertical Displacements - Spillway Training Walls

Leroy Anderson Dam

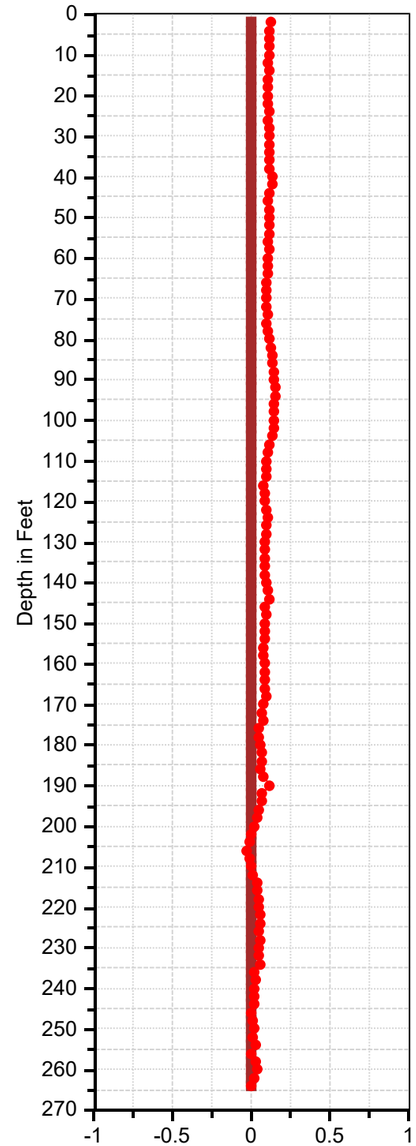
FIGURE
6

PLATE C-14-a A axis (right/left direction)
Incremental Displacement



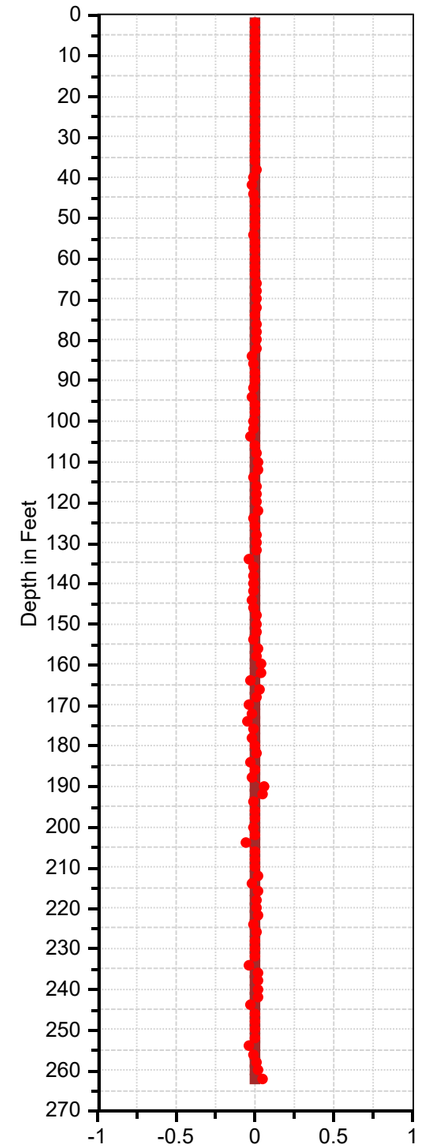
Incremental Displacement (inch)
-left abutment direction +right abutment direction

PLATE C-14-b A axis (right/left direction)
Cumulative Displacement



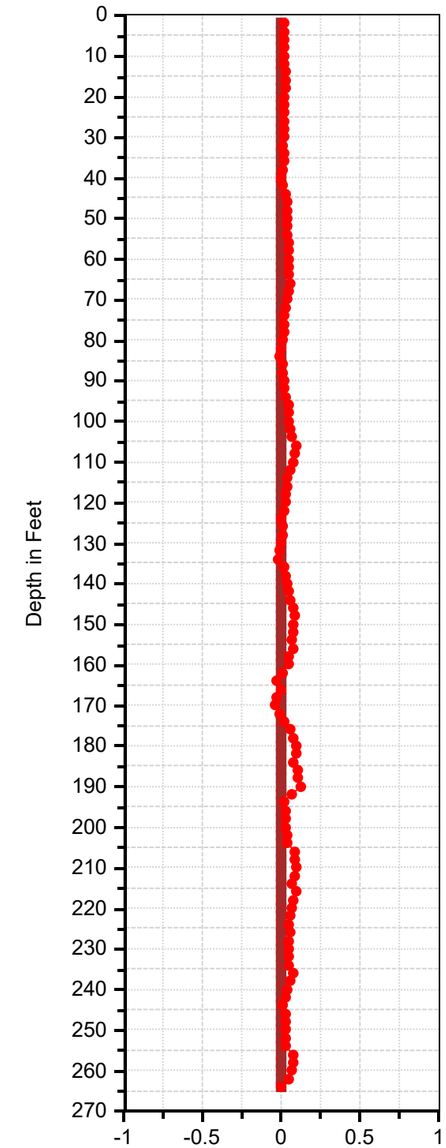
Cumulative Displacement (inch)
-left abutment direction +right abutment direction

PLATE C-14-c B axis (US/DS direction)
Incremental Displacement



Incremental Displacement (inch)
-Downstream direction +Upstream direction

PLATE C-14-d B axis (US/DS direction)
Cumulative Displacement



Cumulative Displacement (inch)
-Downstream direction +Upstream direction

08/10/2016
10/19/2018
Threshold Level ± 0.05 feet
Action Level ± 0.10 feet

Santa Clara Valley Water District

Crest Inclinometer Data
Leroy Anderson Dam

FIGURE
7